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NASA PROGRAM PLAN Fiscal Years, 1981 - 1985  
(National Aeronautics and Space  
Administration) 233 p HC A11/MF A01

N80-31269

CSCL 05A

G3/85 Unclass  
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# NASA Program Plan

Fiscal Years  
1981 Through 1985

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**NASA**  
National Aeronautics and  
Space Administration



NASA PROGRAM PLAN

FISCAL YEARS 1981 THROUGH 1985

AS FOR THE FUTURE, YOUR TASK IS NOT TO  
FORESEE, BUT TO ENABLE IT.

-- SAINT- EXUPÉRY

PREPARED AS OF JANUARY 1980

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## I. INTRODUCTION

This report presents a program plan for NASA's aeronautics and space research and development. As its title indicates, its principal purpose is to present a complete, integrated program for the 5-year period, FY 1981 through 1985. However, both as the result of discussions within the Agency and at the suggestions of our advisors, we are starting to extend the horizon of the planning described in these annual reports. There is evidence of longer range planning throughout this report, and the section describing the Office of Space Transportation System's planned program is an example of the scope we expect to include for all program areas in future reports. That scope consists of detailed planning for five years; a like level of planning out to ten years, but without estimated funding requirements; and projections out to fifteen years or more when those projections are valuable in showing trends or are needed to establish desirable characteristics for earlier activities.

The program described in this report provides initial guidance for NASA's activities over the short-term and, to some extent, the intermediate-term future. The program for FY 1981 is consistent with the budget the President submitted to Congress in January 1980. It contains a limited number of new initiatives, thereby increasing the problem created by the absence of major new initiatives in our FY 1980 program and accentuating further the need for accommodating new initiatives in years beyond FY 1981.

Since submitting his budget, the President has launched his drive to curb inflation. A major feature of that drive is proposed cuts in the federal budget, including NASA's budget. At the time this report is being put into final form, the Administration's proposals are undergoing Congressional action. Although some reductions in NASA's budget appear inevitable, their exact form and extent are not yet defined. Consequently, we know that the program for FY 1981 described in this report will change somewhat, but cannot now say what those changes will be. Changes in FY 1981 will cause changes in the programs for the remaining years of this plan. Those changes should be mostly postponement of events, but with some effect on program content and funding requirements. Program trends should remain essentially as they are. Indeed, we purposely construct our program plans in such a way that they can accommodate those kinds of changes. We include in the planned work for the years beyond the budget year more activities than our funding probably will support. In that way, we are able to adjust to changes imposed upon us and also to provide the Administrator flexibility to modify the Agency's program as work under the program progresses and circumstances change.

This program represents our perception of the work we are technologically ready to undertake, and should undertake, in the interest of the Nation. We believe that it would ensure a sound, logical, technological progression toward achievement of the Nation's goals in aeronautics and space. It is consistent with the responsibilities assigned to NASA by the National Aeronautics and Space Act of 1958, as amended, and with the Civil Space Policy issued by the President in October 1978. All levels of NASA's organization have participated in its development, as have many persons and organizations who are not part of NASA. We welcome comments and suggestions, and will carefully consider all we receive.

To obtain copies of this planning report or general information about NASA's program planning, contact Mr. Thomas W. Chappelle, Code LB-4, National Aeronautics and Space Administration, Washington, DC 20546. For detailed information on the planned technical programs themselves, contact the responsible program offices. Because of the dynamic nature of our programs, you are urged to obtain up-to-date information from the appropriate program offices if you are working in areas related to NASA's programs and the latest status of NASA's plans is important to your work. A late check for program status will be especially important in connection with the Space and Terrestrial Applications program because the anticipated changes in program content, timing, and cost mentioned earlier are expected to be greatest for that program.

NASA's Office of Aeronautics and Space Technology has recently published an analysis of the technology needs of planned and potential space systems. The report consists of three volumes: Volume I, System/Program Technology Needs; Volume II, Space Technology Trends and Forecasts; and Volume III, Opportunity Systems/Programs and Technologies. If you need more detail about the technology base for U.S. space activities than this report contains, request a copy of those volumes from Mr. Stan R. Sadin, Code RS-5, National Aeronautics and Space Administration, Washington, DC 20546.

## II. SUMMARY OF MAJOR FEATURES

This section summarizes, principally in tables and graphs, the major facts about NASA's planned FY 1981 through 1985 program. More detailed information on the plans in the individual program areas is contained in Sections III through X. Section XI is a list of the abbreviations and acronyms that appear in this report, and Section XII is the report's index. Dates throughout this report are fiscal year (FY) dates, October 1 through September 30.

### A. Goals and Objectives

NASA has set the following major goals and objectives to guide the activities it plans to pursue in meeting the responsibilities assigned to it by public law and the Administration:

- o To fill economically and effectively all the transportation and orbital operations needs of science and applications space missions and most transportation needs of national security space missions. This goal will require:
  - Completion of development and production of the Space Shuttle; participation with the Department of Defense in completion of development and production of the Inertial Upper Stage (IUS), and with the European Space Agency in the Spacelab program; development of other auxiliary flight and ground systems required for support of the Shuttle, IUS, and Spacelab; establishment of routine mission operations with those systems; and effective transition from the use of expendable launch vehicles to full operation of the Space Transportation System (Shuttle, Spacelab, and IUS) and the Spinning Solid Upper Stages being developed by industry
  - Development and operation of orbital transfer vehicles to move satellites in low Earth orbit into geostationary, Earth departure, and other high energy orbits; systems to maneuver, service, and retrieve satellites both near to and remote from the Shuttle; and free-flying platforms to host and support aggregated mission equipments and system tests.
- o To apply space technology in four areas that hold promise for immediate or potential benefits to humanity:
  - Remote Sensing: Establishment of a space system to make routine global observations of Earth's atmosphere and land and water surfaces, thereby improving our understanding and forecasting of Earth's environmental behavior, our assessment of Earth's surface productivity, and our ability to develop a "standard" model of the dynamic Earth
  - Communications: Maintenance of U.S. leadership in satellite communications by developing and flight proving technology for wide-band and narrow-band communications to ensure both the telecommunications industry's effective use of the frequency spectrum and orbit space and the extension of services to rural and remote areas

- **Materials Processing:** Development of an understanding of gravitational effects on materials processing for use by researchers and commercial institutions and exploitation of that knowledge to produce unique, low volume, high value materials
- **Technology Transfer:** Assessment of national priorities and user needs, and transfer of space technology for user operations in order to ensure that maximum possible benefits are derived from technologies NASA develops.
- o To continue development of the technology for advanced turboprop aircraft; high-aspect-ratio, supercritical wings; composite structures; active controls; laminar flow control; and fuel-economical turbofan engines that will permit long-range transport aircraft to consume on the order of 50 percent less fuel than current wide-body transports consume.
- o To improve, by a factor of 10 to 100, NASA's ability to acquire, transmit and process data. Two objectives are essential to this goal:
  - Development of technology for sensors and for transmitting and processing data
  - Completion of development and attainment of full operational capability for the Tracking and Data Relay Satellite System.
- o To increase our knowledge about the history of the cosmos and expand our understanding of the evolutionary processes involved. This goal will require:
  - Study of the high-energy universe through observations of celestial gamma rays, x-rays, and cosmic rays in order to understand the non-thermal, nuclear, and elementary particle processes taking place in objects ranging from stars to galaxies, quasars, and the intergalactic medium
  - Testing and verification of the general theory of relativity
  - Detailed comparative planetology studies of the terrestrial planets with next emphasis on obtaining for the entire surface of Venus a radar map providing resolution equivalent to or better than that Mariner 9 obtained at Mars
  - Initial reconnaissance of primordial bodies of the solar system, starting with a fast comet flyby mission and later proceeding with a comet rendezvous mission
  - Continued exploration of the outer planets, with emphasis on Saturn following our current exploration of Jupiter.
- o To advance our fundamental knowledge of how energy is transported from the Sun and through the interplanetary medium, and what effects that energy has on Earth. This goal will require:

- Measurement and analysis of spatial and temporal variations in the Sun and in the plasma between the Sun and Earth to improve our understanding of the coupling between the Sun, solar wind, magnetosphere, ionosphere, and atmosphere
- In situ measurement of the solar environment to determine the origin of energetic particles in the solar wind and the distribution of the Sun's mass.
- o To ensure the good health and effective performance of humans in space, extend selection for space flight to a broader segment of the population, and develop an understanding of the role of gravity on living systems.
- o To understand the origin of life, the distribution of life in the universe, and the relationship between life and its habitat.

Additional goals and objectives specific to individual program areas are presented in the sections of this report describing the plans in those program areas.

#### B. New Initiatives

Table 1 lists the major new initiatives in the FY 1981-1985 program, and Table 2 describes them. Table 3 lists changes in major new initiatives from our FY 1980-1984 plan to this FY 1981-1985 plan.

#### C. Mission Coverage

Figures 1 through 7 show the coverage of important factors that NASA's past, current, planned, and projected space flight missions have provided and will continue to provide in the major program areas of astrophysics, planetary, solar terrestrial, life sciences, environmental observation, resource observation, and tracking and data systems respectively.

The limited amount of space available on Figures 1 through 7 has made it necessary to use acronyms instead of the full names of some systems. Section XI, "Abbreviations and Acronyms," provides the full names for those acronyms, as well as for other acronyms used throughout this report.

#### D. Supporting Research and Technology

Development of technology is part of a continuous process beginning with mostly basic research and ending with operational use. The Office of Aeronautics and Space Technology (OAST) conducts all of NASA's aeronautics technology work and much of the advanced technology development in NASA's space program. In the space program, as a technology matures, the center of activity shifts from OAST to one or more of the other program offices. Most of the technology activity of those offices is related to specific programs and projects, but those offices also perform some non-project technology work. The major areas in which that non-project work is in process, as well as the major areas in which OAST is performing technology work, are described in Table 4 for the aeronautics program and Table 5 for the space program (see pages 23 and 24, respectively). The funding shown in both tables covers work to be performed by universities and industry, and by the NASA field centers listed in the tables.

TABLE 1 -- MAJOR NEW INITIATIVES

PROGRAM	RESPON- SIBLE FIELD CENTERS*	DEVELOPMENT INITIATION DATE					FIRST LAUNCH
		1981	1982	1983	1984	1985	
<u>AERONAUTICS</u>							
Advanced Rotorcraft	ARC,LaRC, LeRC	X					--
Advanced Turboprop, Phase II	LeRC	X					--
Numerical Aerodynamic Simulator	ARC		X				--
Large Primary Composite Structures	LaRC		X				--
Supersonic Cruise Technology Validation	LaRC			X			--
Variable Cycle Experimental Engine(s)	LeRC				X		--
<u>SPACE SCIENCE</u>							
Gamma Ray Observatory	GSFC	X					1985
Venus Orbiting Imaging Radar	JPL		X				1986
Halley Flyby	JPL,MSFC		X				1985
Origins of Plasma in Earth's Neighborhood	GSFC		X				1985
Advanced X-Ray Astrophysics Facility	MSFC			X			1987
Comet Rendezvous	JPL			X			1986
Gravity Probe-B	MSFC				X		1987
Solar Probe	JPL					X	1988
<u>SPACE AND TERRESTRIAL APPLICATIONS</u>							
National Oceanic Satellite System	GSFC	X					1986
Upper Atmosphere Research Satellites	GSFC		X				1985
Ice and Climate Experiment (formerly Climate Research (Cryosphere))	GSFC		X				1986
Multispectral Linear Array	GSFC		X				1985
Gravsat-A	GSFC		X				1985
Landsat-D"	GSFC		X				1984
Landsat-D'"	GSFC		X				1985
Operational Land Observing System (formerly Operational Earth Resources System)	GSFC		X				1987
Wide-Band Program	LeRC		X				1986
Topography Experiment	**			X			1986
Light Intensification, Detection, and Ranging (LIDAR)	GSFC			X			1988
Soil Moisture Research and Assessment Mission (formerly Soil Moisture Mission)	GSFC			X			1986
Applications Data Service	GSFC,JPL, JSC			X			--
Advanced Operational Meteorological System (formerly System 85)	GSFC				X		1988
Magsat-B	GSFC				X		1986
Spaceborne Geodynamics Ranging System	GSFC				X		1987
Advanced Thermal Mapping Applications Satellite (formerly Thermosat)	GSFC				X		1988

\*ARC = Ames Research Center  
 GSFC = Goddard Space Flight Center  
 JPL = Jet Propulsion Laboratory  
 JSC = Johnson Space Center  
 LaRC = Langley Research Center

LeRC = Lewis Research Center  
 MSFC = Marshall Space Flight Center

\*\*To be determined

TABLE 1 -- MAJOR NEW INITIATIVES (CONTINUED)

PROGRAM	RESPON- SIBLE FIELD CENTERS*	DEVELOPMENT INITIATION DATE					FIRST LAUNCH
		1981	1982	1983	1984	1985	
<u>SPACE AND TERRESTRIAL APPLICATIONS (CONTINUED)</u>							
Narrow-Band Program	LeRC				X		**
Ocean Research Mission (formerly Ocean Research)	**					X	1989
Earth Resources Synthetic Aperture Radar	**					X	1989
<u>SPACE TRANSPORTATION SYSTEMS</u>							
Solar Electric Propulsion System	MSFC		X				1986
Satellite Services Near Orbiter	MSFC,JSC		X				1985
Power Extension Package	JSC		X				1984
25-kW Power System	MSFC		X				1985
Large Space Structures Systems Engineering	**		X				1985
Satellite Services Remote from Orbiter	MSFC			X			1986
Science and Applications Platform	MSFC			X			1986
Materials Experiment Carrier	MSFC			X			1986
Geostationary Platform Demonstration	MSFC			X			1987
Space Operations Center Core	JSC				X		1987
Space Operations Center Modules	JSC				X		1987
Orbital Transfer Vehicle	MSFC					X	After 1990

\* JSC = Johnson Space Center  
 LeRC = Lewis Research Center  
 MSFC = Marshall Space Flight Center

\*\*To be determined

TABLE 2 -- DESCRIPTION OF MAJOR NEW INITIATIVES

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
<u>AERONAUTICS</u>		
Advanced Rotorcraft	To develop technology for all-weather, higher speed, efficient, economical, comfortable rotorcraft.	None
Advanced Turboprop, Phase II	To develop technology for efficient, reliable, and acceptable operations of advanced turboprop-powered aircraft at cruise speeds ranging from Mach 0.7 to Mach 0.8	Aerodynamics, structures, and acoustics technology for large-scale, high-speed propellers; fuselage noise attenuation technology
Numerical Aerodynamic Simulator	To provide special computer facility for numerical simulation of complex flow of fluids in aerodynamics and Earth's atmosphere	Computation speed about forty times that of current supercomputers
Large Primary Composite Structures	To apply composite structures in fuselage and wings of transport aircraft	Large structure fabrication techniques
Supersonic Cruise Technology Validation	To develop selected supersonic technologies to point of acceptable risk for subsequent establishment of technological readiness	Advanced core technology, nacelle-airframe integration technology, and high-speed aircraft structures technology
Variable Cycle Experimental Engine(s)	To conduct full-scale ground test verification of variable cycle engine performance, efficiency, and noise and pollution reduction	Variable cycle engine components and advanced core technology
<u>SPACE SCIENCE</u>		
Gamma Ray Observatory	To study high-energy nuclear and elementary particle processes in universe by observing gamma-ray line and continuum emissions from celestial sources	None
Venus Orbiting Imaging Radar	To map with radar Venus' entire surface with resolution better than 1 kilometer and spot resolution of 100 meters to determine geological evolution of Venus; to study Venus' atmosphere	Improved propulsion or aerobraking for deceleration at Venus
Halley Flyby	To obtain first close-up look at a comet and to initiate program of study of small bodies of solar system	None

TABLE 2 -- DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
<u>SPACE SCIENCE (CONTINUED)</u>		None
Origins of Plasma in Earth's Neighborhood	To investigate coupling between magnetosphere, solar wind, and ionosphere and to investigate energy and plasma transportation, storage, and dissipation or loss	Advanced X-ray detectors; highly precise X-ray mirror manufacturing techniques
Advanced X-Ray Astrophysics Facility	To perform X-ray studies of quasars, galaxies, clusters of galaxies, and intergalactic medium with order-of-magnitude improvement in sensitivity and spectral and spatial resolution	Rapid-response atmospheric sensors; dust analysis methods; solar electric propulsion
Comet Rendezvous	To obtain first studies of nucleus of comet	None
Gravity Probe-B	To perform fundamental test of general relativity by measuring precession of gyroscope in Earth orbit	Thermal control; telecommunications; advanced drag-free systems; advanced instruments
Solar Probe	To make in situ measurements of interplanetary environment as close to Sun's surface as three solar radii, to increase understanding of processes that heat and drive solar wind and accelerate solar energetic particles, to test general relativity, and to investigate, indirectly, internal structure of Sun	Scanning multichannel radiometer with 4-meter antenna and ground resolution of 10 kilometers
<u>SPACE AND TERRESTRIAL APPLICATIONS</u>		
National Oceanic Satellite System	To demonstrate limited operational capability for observing the oceans to describe ocean processes, ice dynamics, and coastal processes	Attitude determination with measuring accuracy of 0.003 degree; 18- to 24-month cryogenics for instruments; advanced microwave limb sounder, far infrared spectrometer, and laser heterodyne radiometer; central data system with remote access
Upper Atmosphere Research Satellites	To measure active constituents, temperatures, and other dynamic characteristics of stratosphere and mesosphere, and to observe interaction of stratosphere and mesosphere	Imaging radar; radar and laser altimeters; multichannel microwave radiometer; data transmission and processing
Ice and Climate Experiment	To study Earth's ice and its interaction with the atmosphere, and time-lapse with climate	Extension of linear array to mid-infrared (1 to 4 microns)
Multispectral Linear Array	To observe agriculture, water resources, lithology, and biotany with improved temporal resolution and	

TABLE 2 -- DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
Multispectral Linear Array (Continued)	providing discrimination and identification of types of vegetation and rocks, as well as measurements of areas covered by each	
Gravsat-A	To map Earth's gravity field at improved accuracy and resolution for studies of solid Earth processes and ocean circulation	Measurement of satellite-to-satellite tracking velocity increments of 0.003 millimeter per second
Landsat-D" and Landsat-D"	To provide for Landsat data continuity between Landsats D and D' and for initiation of data acquisition by Operational Land Observing System	None
Operational Land Observing System	To provide Earth resources remote sensing data on operational basis to users within 72 hours of data acquisition	Capability to process 100 Thematic Mapper and 200 Multispectral Linear Array scenes per day in a serial mode with 95 percent probability of success
Wide-Band Program	To establish conceptual designs, develop critical technology, and determine need for flight verification tests for K-band satellite communications system	Multibeam, spaceborne, 20-GHz antenna; high-sensitivity, 30-GHz receivers; onboard high-speed switching system for interconnecting beams
Topography Experiment	To increase understanding of global circulation of oceans and demonstrate usefulness of remotely sensed data in studying oceans	None
Light Intensification, Detection, and Ranging (LIDAR)	To study atmospheric transport models and global flow of water vapor and pollutants in troposphere and lower atmosphere	Narrow-band Nd:YAG laser and pulsed CO <sub>2</sub> laser
Soil Moisture Research and Assessment Mission	To measure amount of moisture in soil by use of passive and active microwave, visual, and infrared techniques	Solid-state thermal infrared sensors; 18- to 20-meter, high precision, parabolic antenna; low noise, passive, microwave detectors
Applications Data Service	To combine existing and planned data systems into integrated structure by developing network service for data transmission and integration	To be determined
Advanced Operational Meteorological System	To develop operational meteorological satellite system for studying severe storms and measuring surface temperatures, winds, clouds, and Earth's radiation budget to understand atmospheric processes and improve accuracy of mid-range (2- to 14-day) weather forecasts	Scanning multichannel radiometer with 4-meter antenna and ground resolution of 10 kilometers

TABLE 2 -- DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
<b>SPACE AND TERRESTRIAL APPLICATIONS (CONTINUED)</b>		
Magsat-B	To investigate secular variations and decay of Earth's magnetic field over extended period	None
Spaceborne Geodynamics Ranging System	To obtain rapid, high-density, three-dimensional measurements of relative positions within $\pm 1$ centimeter to determine strain accumulation in seismically active zones	Long-life rods for solid-state lasers; low-cost, ground-based, laser retroreflectors
Advanced Thermal Mapping Applications Satellite	To develop satellites to collect narrow-band thermal data with high spatial resolution	Narrow-band, solid-state, thermal infrared detectors
Narrow-Band Program	To establish conceptual designs, develop critical technology, and determine need for flight verification tests for low-volume communications for emergencies, disasters, and other such uses	Large, spaceborne, multibeam, 900-MHz antenna; low-cost ground terminals; onboard switching system to handle large number of interconnections
Ocean Research Mission	To increase understanding of global circulation of oceans and demonstrate usefulness of remotely sensed data in studying oceans	Precise, high-resolution radar altimeter; advanced microwave radiometer; visible-infrared instruments; data transmission and processing
Earth Resources Synthetic Aperture Radar	To support applications research in mineral and petroleum exploration and water and vegetation monitoring by use of multidisciplinary radar research facility	Multifrequency, multipolarization, multiple-look-angle antenna system
<b>SPACE TRANSPORTATION SYSTEMS</b>		
Solar Electric Propulsion System	To develop low-thrust ion propulsion system	Lightweight, high-specific-power solar arrays; long-life ion thrusters; power-processor thruster control
Satellite Services Near Orbiter	To develop capabilities for placement, retrieval, and in-orbit maintenance and repair of satellites and for retrieval of unstable satellites and space debris, all within immediate vicinity of Orbiter	Regenerative, high-pressure suit, portable life-support systems, and maneuvering unit for extra-vehicular activity; space tools, end effectors, and Cherry Picker for Remote Manipulator System, and television systems
Power Extension Package	To develop Shuttle-borne system to provide 12 kilowatts (average) of solar electric power to Shuttle and its payloads	None

TABLE 2 -- DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
<u>SPACE TRANSPORTATION SYSTEMS</u> (CONTINUED)		
25-kW Power System	To develop system to provide 25 kilowatts (average) of solar electric power to Shuttle and its payloads and to free-flying payloads in low Earth orbit	None
Large Space Structures Systems Engineering	To conduct level-of-effort flight program to develop materials, tools, and techniques for assembling in orbit first generation of large space structures	Advanced composite materials; space fabrication machinery; techniques for testing large structures
Satellite Services Remote from Orbiter	To develop capabilities for placement, retrieval, and in-orbit maintenance and repair of satellites and for retrieval of unstable satellites and space debris, all at distances from Orbiter of hundreds and thousands of miles	Teleoperator Maneuvering System; front end kits to despin, grapple, and capture unstable objects; front end with mechanism for changing spacecraft modules
Science and Applications Platform	To develop free-flying platform for use with 25-kW Power System to simultaneously support wide range of science and applications payloads	None
Materials Experiment Carrier	To develop pallet that will be carried to space on early Shuttle flights and docked with 25-kW Power System to provide, up to 90 days, interface systems between 25-kW Power System and materials processing experiments mounted on the pallet	Advanced thermal energy dissipation systems; remote visual monitoring systems; low-g platform stability control; in-orbit servicing
Geostationary Platform Demonstration	To develop general purpose platform to be used in lieu of numerous specialized satellites for communications, Earth observation, and space science payloads	Platform figure and attitude control; weight and size of beam switching systems; control of beam pointing; control of radio-frequency interference
Space Operations Center (SOC):	To develop Shuttle-serviced, permanent facility in low Earth orbit	
Core	To develop SOC core element containing service modules to provide electrical power; guidance, control, stabilization, reaction control, and communications and interconnection interfaces for Shuttle and modules of various kinds	Attitude stabilization, and guidance controls; mechanical systems; electric power
Modules	To develop SOC habitation, logistics, flight support, and construction modules	Life support systems

TABLE 2 -- DESCRIPTION OF MAJOR NEW INITIATIVES (CONTINUED)

NEW INITIATIVE	OBJECTIVE	NEW TECHNOLOGY REQUIRED
<p><u>SPACE TRANSPORTATION SYSTEMS</u> <u>(CONTINUED)</u></p> <p>Orbital Transfer Vehicle</p>	<p>To develop vehicle to transport payloads from Shuttle to geosynchronous orbit and to service them there</p>	<p>Advanced liquid oxygen-hydrogen engines, including high- and low-thrust throttling, long-life components, and human-related quality; in-orbit propellant transfer and propellant-system maintenance; insulation for high-performance cryogenics; designs for lightweight structures</p>

TABLE 3 -- CHANGES IN MAJOR NEW INITIATIVES  
FROM 1980 THROUGH 1984 PLAN

INITIATIVES ADDED

<u>INITIATIVE</u>	<u>INITIATION DATE</u>
Landsats D" and D'"	1982
Topography Experiment	1983
Applications Data Service	1983
Magsat-B	1984
Space Operations Center Core	1984
Space Operations Center Module	1984

MISSION REDEFINED

1982 Halley Flyby/Tempel 2 Rendezvous initiative now 1982 Halley Flyby initiative and 1983 Comet Rendezvous initiative

DEVELOPMENT ARRANGEMENT CHANGED

1982 Special Computer Facility initiative transferred from Construction of Facilities Division to Aeronautics program of Office of Aeronautics and Space Technology and renamed Numerical Aerodynamic Simulator

INITIATION DATE CHANGED

<u>NEW INITIATIVE</u>	<u>INITIATION DATE</u>	
	<u>80-84 PLAN</u>	<u>81-85 PLAN</u>
Venus Orbiting Imaging Radar	1981	1982
Origins of Plasma in Earth's Neighborhood	1981	1982
Gravity Probe-B	1982	1984
Solar Probe	1984	1985
Upper Atmosphere Research Satellites	1981	1982
Multispectral Linear Array (formerly Multispectral Resource Sampler)	1981	1982
Light Intensification, Detection, and Ranging (LIDAR) (entitled Multi-User Lidar System in FY 1980-1984 plan and not listed as a major new initiative because estimated funding was low)	1981	1983
Soil Moisture Research and Assessment Mission (formerly Soil Moisture Mission)	1982	1983
Advanced Operational Meteorological System (formerly System 85)	1981	1984
Advanced Thermal Mapping Applications Satellite (formerly Thermosat)	1983	1984

TABLE 3 -- CHANGES IN MAJOR NEW INITIATIVES  
FROM 1980 THROUGH 1984 PLAN  
(CONTINUED)

INITIATION DATE CHANGED

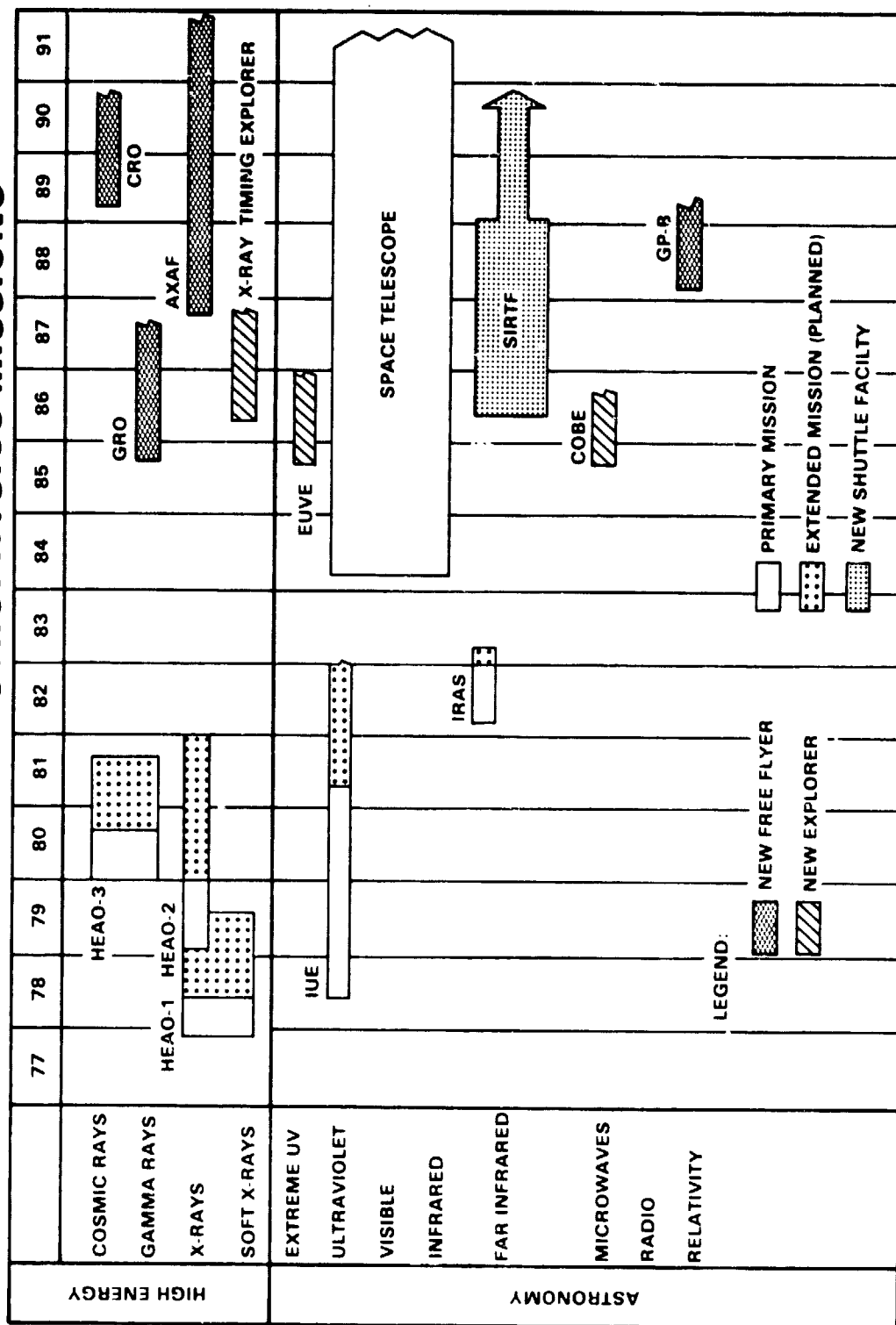
<u>NEW INITIATIVE</u>	<u>INITIATION DATE</u>	
	<u>80-84 PLAN</u>	<u>81-85 PLAN</u>
Earth Resources Synthetic Aperture Radar	1983	1985
Ocean Research Mission (formerly Ocean Research)	1983	1985
Solar Electric Propulsion System	1981	1982
Satellite Services Near Orbiter (formerly part of Satellite Services)	1981	1982
Power Extension Package	1981	1982
25-kW Power System (formerly 25-kW Power Module)	1981	1982
Large Space Structures Systems Engineering	1981	1982
Satellite Services Remote from Orbiter (formerly part of Satellite Services)	1982	1983
Science and Applications Platform	1982	1983
Materials Experiment Carrier (formerly Materials Experimentation Carrier)	1982	1983
Geostationary Platform Demonstration (formerly Large Geostationary Platform)	1982	1983
Space Power Systems Engineering	1982	*
Orbital Transfer Vehicle	1983	1985

INITIATIVES CANCELLED

Stereosat  
Advanced Geology Satellite  
Landsat-D Refurbishment  
Space Vacuum Research Facility  
Large Advanced Antenna System

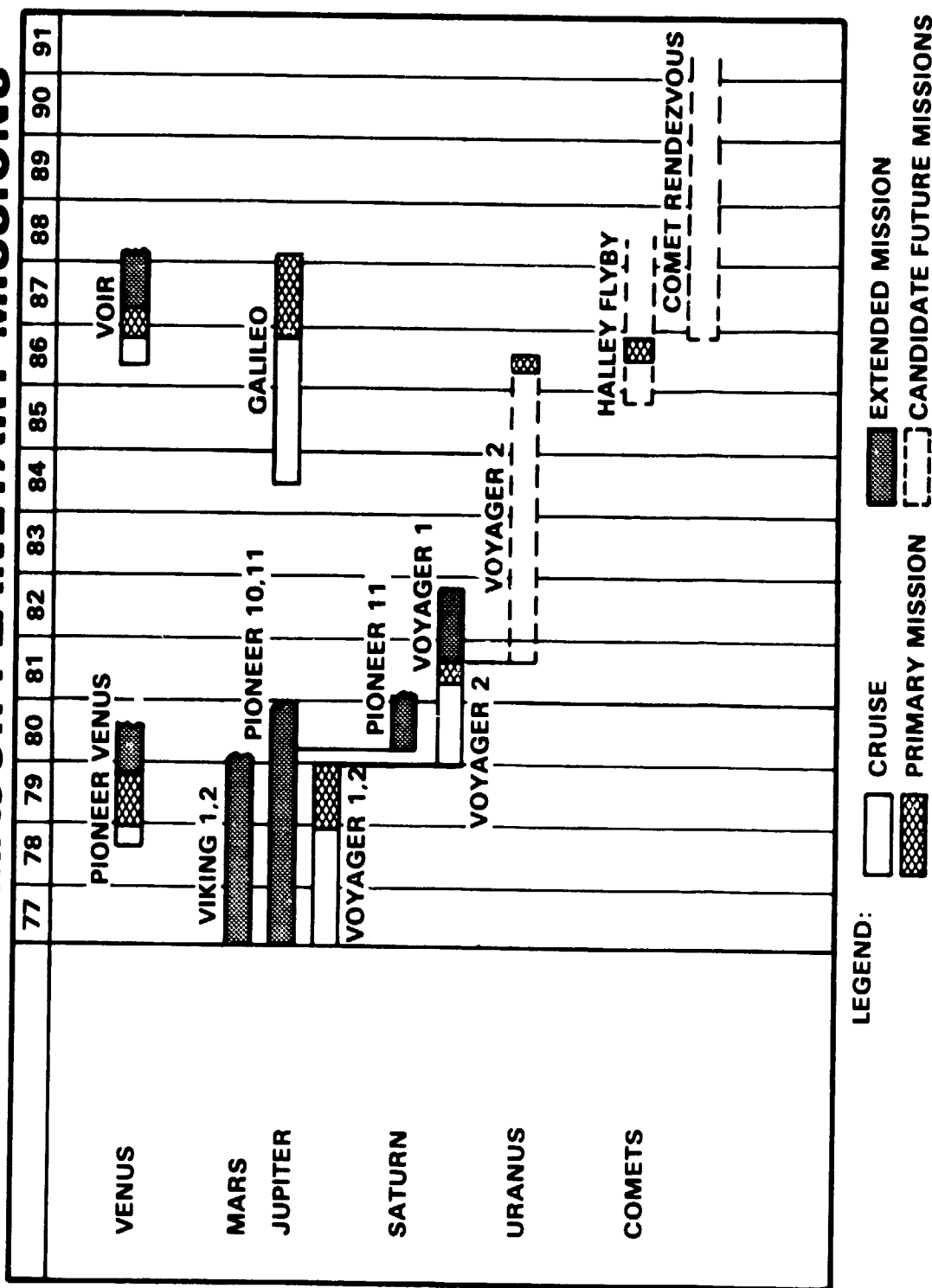
\*To be determined

# FIGURE 1 — MAJOR ASTROPHYSICS MISSIONS



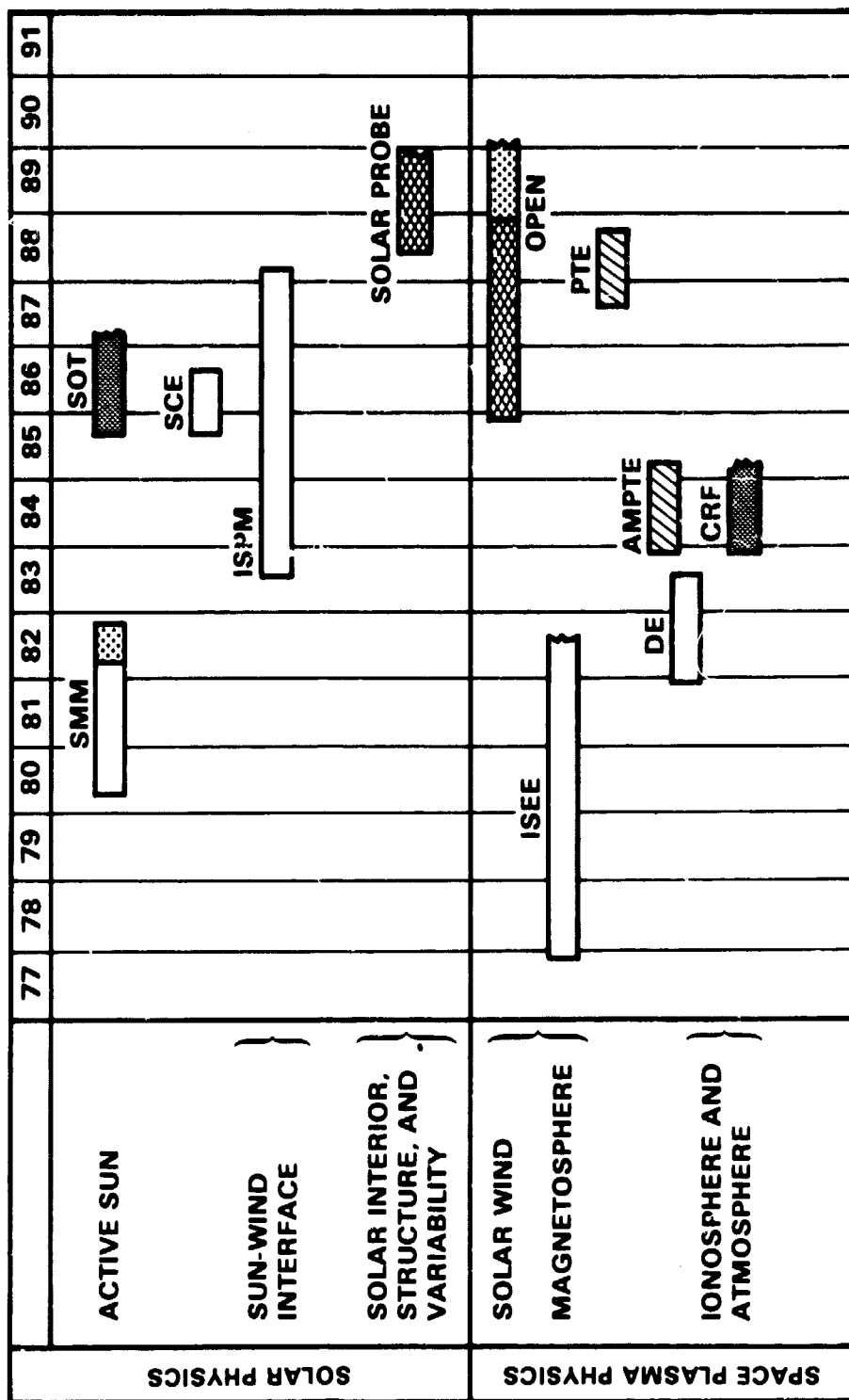
NASA HQ 890.4209 (1)  
7-25-80

# FIGURE 2 — MAJOR PLANETARY MISSIONS



NASA HQ P80-4213 (1)  
7-25-80

# FIGURE 3 — MAJOR SOLAR TERRESTRIAL MISSIONS



LEGEND:

- PRIMARY MISSION (White box)
- EXTENDED MISSION (Dotted box)
- NEW SHUTTLE FACILITY (Diagonal lines)
- NEW FREE FLYER (Cross-hatched box)
- NEW EXPLORER (Solid black box)

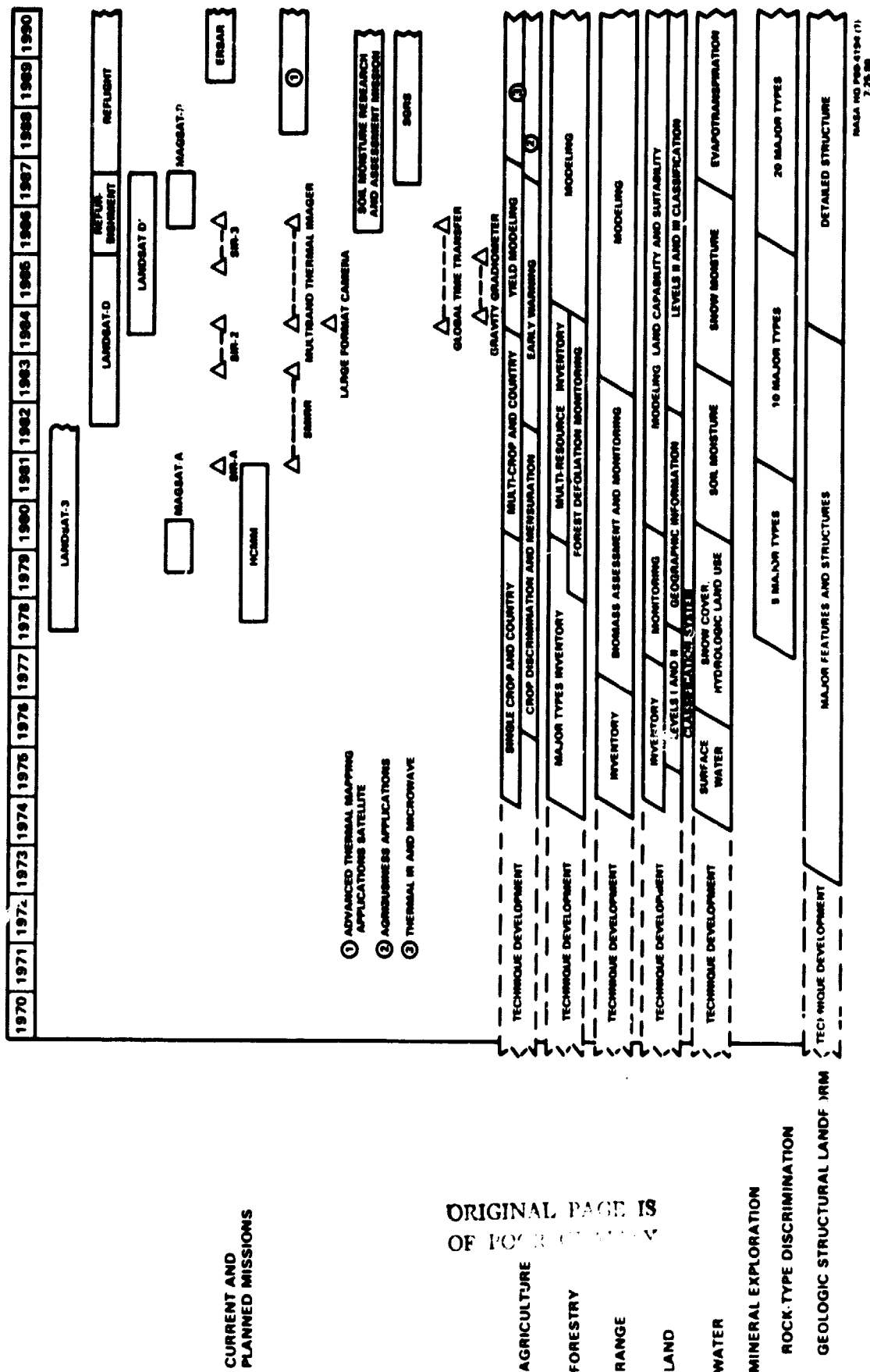
NASA HQ POB-4212 (1)  
7-25-80



# FIGURE 5 — MAJOR ENVIRONMENTAL OBSERVATION MISSIONS

	<div> <div>197019711972197319741975197619771978197919801981198219831984198519861987198819891990</div> <div> <div>TIROS</div> <div>GOES</div> <div>NIMBUS</div> <div>ADVANCED METEOROLOGICAL SATELLITE</div> </div> </div>
CURRENT AND PLANNED MISSIONS	<div> <div> <div>GEOS</div> <div>SAGE</div> <div>ERBS</div> <div>UARS</div> <div>TOPEX</div> <div>NOSS</div> <div>ICEX</div> </div> <div> <div>SEASAT</div> <div>LIDAR</div> </div> <div>ACPL, HALOE, ATMOS</div> <div>SHUTTLE PAYLOADS</div> </div>
ATMOSPHERE	
SOLAR CONSTANT	1.2% 0.5%
RADIATION BUDGET	±5%
ATMOSPHERIC CHEMISTRY	CHEMISTRY, RADIATION, AND DYNAMICS
OZONE	5% 2%
CLOUDS	COVERAGE - TYPES - ALTITUDE (STEREO)
TEMPERATURE PROFILE	2.0% 2.5%
STRATOSPHERE AEROSOL	ADVANCED TEMPERATURE SOUNDER
TROPOSPHERE AEROSOL	IMPROVED SPATIAL RESOLUTION
PRECIPITATION (LAND)	10% 1%
LIGHTNING	LIGHTNING MAPPER
OCEAN PROCESSES	
SEA STATE	PROOF OF CONCEPT
GEOID	1M
CIRCULATION	30-60 CM 20 CM
ICE (CONCENTRATION)	15% 5 - 10%
COASTAL ZONE	IMPROVED SPATIAL RESOLUTION

# FIGURE 6 — MAJOR RESOURCE OBSERVATION MISSIONS



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OF POOR QUALITY

# **FIGURE 7 — GROWTH IN TRACKING AND DATA SYSTEMS CAPABILITIES**

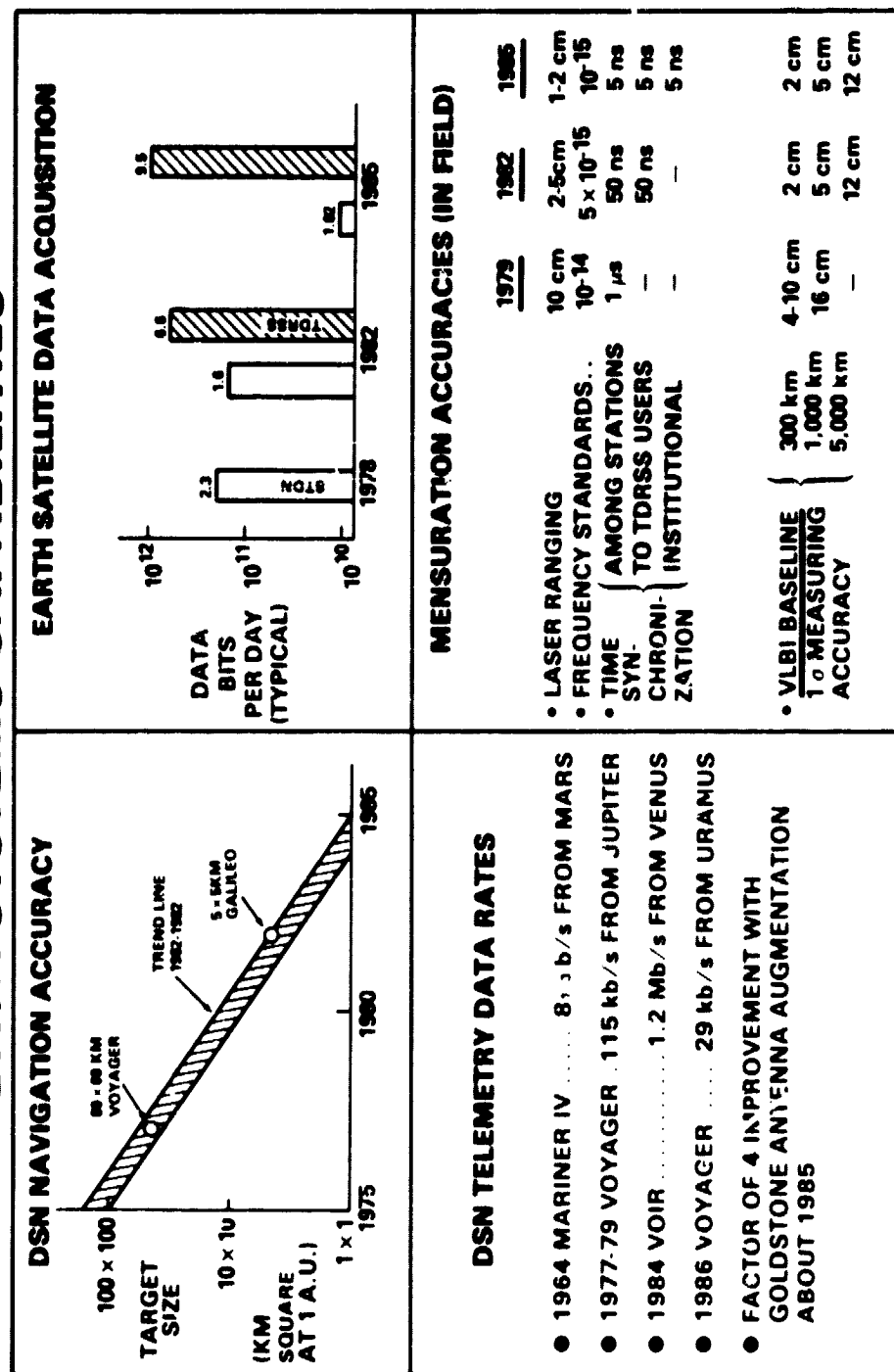


TABLE 4 -- MAJOR NON-PROJECT AERONAUTICS RESEARCH AND TECHNOLOGY

PROGRAM AREA	FUNDING IN 1981 (\$M)	FIELD CENTERS INVOLVED *	OBJECTIVES
<b>AERONAUTICS</b>			
Fundamental Research and Technology	107	ARC, DFRC, JSC, LaRC, LeRC	Conduct continuing fundamental research in individual technical disciplines that are broadly applicable to many, frequently all, classes of aircraft, with emphasis on avionics and controls, fuels, design data and methods, and advanced materials
Transport Aircraft	51	ARC, DFRC, LaRC, LeRC, (JPL, JSC, MSFC, WFC)	Improve operating efficiency, safety, and environmental acceptability of subsonic transports through advances in aerodynamics, structures, avionics, controls, and operating procedures
General Aviation	8	LaRC, LeRC	Provide efficient aerodynamics; reduce drag; determine avionics and systems requirements; develop efficient, low-noise propulsion systems; improve stall-spin characteristics and structural crash-worthiness
Low-Speed Aircraft	35	ARC, LaRC, LeRC	Increase technology base in rotorcraft aerodynamics and propulsion; evaluate, in flight, composite materials components, avionic components, and flying qualities; develop data base and prediction methods for establishing design criteria for military and civilian V-STOL aircraft; complete flight experiments in STOL part of program
High-Speed Aircraft	33	ARC, DFRC, LaRC, LeRC	Study and understand major technical problems related to military and civilian supersonic cruise aircraft; validate critical technologies for high-temperature structures; improve performance and effectiveness of high-performance aircraft and missiles; conduct flight research experiments emphasizing integration of airframe, propulsion and controls
Advanced Propulsion	56	ARC, DFRC, LaRC, LeRC	Advance technology of aeronautical propulsion systems to attain improved performance, lower fuel consumption, and reduced noise and emissions in advanced engines

\*ARC = Ames Research Center      JSC = Johnson Space Center      MSFC = Marshall Space Flight Center  
 DFRC = Dryden Flight Research Center      LaRC = Langley Research Center      WFC = Wallops Flight Center  
 JPL = Jet Propulsion Laboratory      LeRC = Lewis Research Center

TABLE 5 -- MAJOR NON-PROJECT SPACE RESEARCH AND TECHNOLOGY

PROGRAM AREA	FUNDING IN 1981 (\$M)	FIELD CENTERS INVOLVED *	OBJECTIVES
<u>OFFICE OF SPACE SCIENCE (OSS)</u>			
Theory and Laboratory Work	22	ARC, GSFC, JPL, MSFC	Evaluate interactions of Mars' soil and atmosphere; develop theory in astronomy, solar physics, and related areas of physics such as atomic parameters; analyze magnetospheric processes; interpret and combine results
Ground-Based Observations	7	ARC, GSFC, JPL, JSC	Complement space measurements; provide basic data for space missions; supplement space data; maintain facilities
Instrument Development	7	GSFC, JPL	Develop detectors and experimental techniques in all areas, including manned support systems
Data Analysis	19	ARC, GSFC, JPL, JSC, MSFC	Provide methods for interpreting data; extend use of data; make comparative studies of data
Suborbital Programs	3	ARC, GSFC, JPL, JSC, MSFC	Test concepts for advanced instruments; determine special opportunities for solar physics experimentation; obtain supporting data for magnetospheric studies; carry out astrophysics research with unique airborne observatory
Space Medicine	14	JSC	Provide medical services to Shuttle crews; develop requirements for future work; determine cause of and methods for preventing observed changes; maintain medical standards
Planetary and Space Biology	6	ARC, JPL	Conduct biomedical research related to stresses on humans in space flight; study life-support requirements for long-term space flight, including control of ecological environment; study biological evolution in planetary context and distribution of life in the universe
Advanced Development and Mission Studies	27	ARC, GSFC, JPL, MSFC	Perform definition studies for future missions of Explorer class of satellites, Spacelab, and major free-flying satellites; participate in development of ion propulsion systems; define planetary flight program
<u>OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS (OSTA)</u>			
Global Weather (including Global Atmospheric Research Program	11	GSFC, JPL, LaRC, MSFC, WFC	Define, develop, and demonstrate concepts for new and improved sensors; study atmospheric behavior and modeling; study and demonstrate space data for improving forecasts

\* ARC = Ames Research Center      JSC = Johnson Space Center      WFC = Wallops Flight Center  
 GSFC = Goddard Space Flight Center  
 JPL = Jet Propulsion Laboratory      LaRC = Langley Research Center  
 MSFC = Marshall Space Flight Center

TABLE 5 -- MAJOR NON-PROJECT SPACE RESEARCH AND TECHNOLOGY (CONTINUED)

PROGRAM AREA	FUNDING IN 1981 (\$M)	FIELD CENTERS INVOLVED *	OBJECTIVES
<u>OSTA (CONTINUED)</u>			
Climate	8	ARC, GSFC, JPL, LaRC, WFC	Develop data base; study climate variables, modeling, and analysis; define climate observing system requirements
Severe Storms	5	GSFC, KSC, MSFC	Perform theoretical studies and research to provide basic understanding; develop and demonstrate techniques for interpreting remotely sensed data; define and develop concepts for instruments; develop forecasting models
Environmental Quality: Tropospheric Stratospheric	4 5	GSFC, JPL, LaRC	Study and demonstrate use of remotely sensed data for monitoring atmospheric and water pollution; conduct studies to define sensors and systems for monitoring pollution
Ocean Processes (including Water Quality)	13	GSFC, JPL, LaRC, LeRC, NSTL, WFC	Develop data base; demonstrate use of remotely sensed data to solve oceans and ice research and operational problems; study ocean and coastal behavior; define and demonstrate concepts for advanced sensors
Upper Atmosphere	13	ARC, GSFC, JPL, LaRC, LeRC	Conduct field measurements, laboratory studies, theoretical studies, and data analysis to expand scientific knowledge of Earth's stratosphere and mesosphere and to develop ability to assess threats to upper atmosphere
Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing	33	ARC, GSFC, JSC, LaRC, NSTL	Develop remote sensing techniques to augment or replace existing sources of information or provide new information for agricultural commodity forecasts and early warning and assessment of commodity condition
Renewable Resources Applied Research and Data Analysis (AR&DA)	8	ARC, GSFC, JSC, LaRC, NSTL	Research quantitative estimating techniques for assessing crop, range-land, and forest conditions
Non-Renewable Resources AR&DA	4	GSFC, JPL	Study ways to improve capability to interpret Earth's geologic structure and chemical composition from space, using visual, infrared, thermal, and active and passive microwave techniques; interpret magnetic and gravitational anomalies; research vegetative anomalies as indicators of underlying mineralization
Application Pilot Tests	3	ARC, GSFC, JSC, NSTL	Test techniques to detect land cover changes, inventory Navajo resources, delineate urban areas, inventory vegetation related to wildlife habitats, inventory forest resources, assess irrigated lands, measure cotton crops, demonstrate land productivity, and map channel contours

\* ARC = Ames Research Center  
 GSFC = Goddard Space Flight Center  
 JPL = Jet Propulsion Laboratory  
 JSC = Johnson Space Center  
 KSC = Kennedy Space Center  
 LaRC = Langley Research Center  
 LeRC = Lewis Research Center  
 MSFC = Marshall Space Flight Center  
 NSTL = National Space Technology Laboratories  
 WFC = Wallops Flight Center

TABLE 5 -- MAJOR NON-PROJECT SPACE RESEARCH AND TECHNOLOGY (CONTINUED)

PROGRAM AREA	FUNDING IN 1981 (\$M)	FIELD CENTERS INVOLVED *	OBJECTIVES
<u>OSTA (CONTINUED)</u>			
Mission Definition and Advanced Studies	4	GSFC, JPL, JSC	Study feasibility of and identify options for future resource observation missions; support system definition studies on Operational Land Observing System and potential Earth resources research missions
Materials and Process Research	6	JPL, LaRC, MSFC	Conduct ground-based research on material processes and properties to develop science and technology and advanced concepts for space experiments
Advanced Technology Development	1	JPL, LaRC, LeRC, MSFC	Provide technology for basic equipment and instrumentation for ground and space investigations of materials processing
Equipment Definition Studies	2	JPL, MSFC	Evaluate system approaches to design and integration of materials processing STS payload equipment, select optimum approaches, and evaluate costs
Advanced Communications Research	14	LeRC	Initiate research on technical feasibility and costs of key subsystems at 20 and 30 GHz, such as multibeam antennas, onboard switching systems, low-noise and high-power amplifiers
Wide-Band 20/30 GHz Definition	3	LeRC	Review alternatives to flight testing key 20 and 30 GHz subsystems to ensure their transition to private sector and to minimize NASA's flight-test costs
<u>ENERGY SYSTEMS</u>	4	JPL, LeRC, MSFC	Use NASA's aeronautics and space technologies, experience, and facilities to support needs of Department of Energy and other government organizations in implementing national energy policy
<u>SPACE TECHNOLOGY</u>			
Disciplinary R&T	66	ARC, GSFC, JPL, JSC, LaRC, LeRC, MSFC	Conduct continuing research in individual technical disciplines that are broadly applicable to many, frequently all, classes of space vehicles and systems, with emphasis on automation, structural dynamics, entry phenomena, advanced propulsion, and power concepts
Information Systems	28	ARC, GSFC, JPL, JSC, KSC, LaRC, LeRC, MSFC	Develop capabilities for acquiring, processing, and disseminating data in form responsive to user needs
Spacecraft Systems	11	GSFC, JPL, JSC, KSC, LaRC, LeRC, MSFC	Develop technology for space structures requiring new techniques and components for their in-orbit construction, deployment, and operation

\* ARC = Ames Research Center      JSC = Johnson Space Center      LeRC = Lewis Research Center  
 GSFC = Goddard Space Flight Center      KSC = Kennedy Space Center      MSFC = Marshall Space Flight Center  
 JPL = Jet Propulsion Laboratory      LaRC = Langley Research Center

TABLE 5 -- MAJOR NON-PROJECT SPACE RESEARCH AND TECHNOLOGY (CONTINUED)

PROGRAM AREA	FUNDING IN 1981 (\$M)	FIELD CENTERS INVOLVED *	OBJECTIVES
SPACE TECHNOLOGY (CONTINUED)			
Transportation Systems	8	ARC, JSC, LaRC, LeRC, MSFC	Develop technology for more fully reusable space transportation system with substantially lower operating costs
OFFICE OF SPACE TRACKING AND DATA SYSTEMS			
Tracking, Orbit Determination, and Ground-Based Navigation	3	GSFC, JPL	Develop ground-based technology for cost-effective support of planetary targeting requirements that will provide more accuracy, of missions with high velocities and accelerations, and of very long baseline interferometer, planetary radar, navigational accuracy analysis, experiments, and demonstrations
Spacecraft to Ground Communications Teleme- try and Command	4	GSFC, JPL	Develop ground-based technology for missions requiring higher and more variable data rates, higher frequencies, data acquisition and command at greater distances, coded signals and high-rate video or radar imaging; develop new techniques for and ensure availability of cost-effective support
Network Control and Operations Technology	2	GSFC, JPL	Develop, for network and station control and operations, techniques for such functions as operation of unattended systems, monitoring and control of radio-frequency interference, and systems testing in an operational environment
Data Handling and Processing	2	GSFC, JPL	Develop techniques, data processing, and control software for tracking and data acquisition functions such as integration through networking, control of program operations, and operation of modeling networks and of radio-frequency interference data-processing network

\* ARC = Ames Research Center      JSC = Johnson Space Center      MSFC = Marshall Space Flight Center  
 GSFC = Goddard Space Flight Center      LaRC = Langley Research Center  
 JPL = Jet Propulsion Laboratory      LeRC = Lewis Research Center

To be able to assess more accurately the anticipated requirements for and the status of technology, and to coordinate the efforts of the program offices, the NASA Council created, in 1978, the mechanism of "cross-cutting technology teams." The teams consist of representatives from all involved program offices and report to the NASA Council. Cross-cutting technology teams supported the FY 1981-1985 planning process in the areas of large space systems, space electrical power, chemical propulsion, communications, sensors, and data management.

Each team, except the one responsible for communications, concluded that expansion of work in its program area is vital to the Agency's planned program. Each team endorsed current programs as fine-tuned products of the intensive restructuring the programs have undergone during the last few years as a result of assessments conducted by OAST and the other program offices, NASA's field centers, and advisory groups. However, each team identified specific requirements for program enhancements that it deemed critical to the enablement of missions included in the Agency's planned program. The recommendations of those teams are as follows:

- o Chemical Propulsion. This team responded most strongly in identifying program deficiencies. It confirmed the concern expressed by many sources, such as industry, the Department of Defense, and Congress, that the U.S. industrial base in chemical propulsion is in jeopardy. It recommended that enhancement of the Chemical Propulsion Research and Technology Base program be given the highest possible priority and that development of systems technologies be initiated on a priority basis for focused needs such as low-thrust propulsion for orbit transfer vehicles. All of NASA's advisory groups that deal with propulsion firmly endorsed those recommendations.
- o Space Electrical Power. This team recommended enhancement of the planned program to provide the multihundred-kW power system that will be needed to enable future missions. Specific areas requiring emphasis are high-voltage distribution, improvement in the efficiency of electrical energy storage, and new techniques for thermal energy dissipation and distribution.
- o Large Space Systems. This team recommended expansion of the Agency's programs that will lead to a flight demonstration program and of the Agency's activities oriented principally to structures and materials that will develop elements of platform services, assembly, maintenance, and repair.
- o Sensors. This team strongly recommended major expansion of the basic program, with emphasis on broader spectral range, greater resolution, and incorporation of sophisticated processing technology to provide "smart" sensing techniques.
- o Data Management. This team recommended extending OAST's data systems program to include development of capabilities required for the Office of Space and Terrestrial Applications' Applications Data Service and the Office of Space Science's National Space Science Data Center at Goddard Space Flight Center.

## E. International Programs

From its early years, NASA has conducted cooperative programs with agencies in other countries. Indeed, it is charged to do so by the National Aeronautics and Space Act. Mutual benefit and no exchange of funds form the basis for the programs. There is every indication that the number of cooperative programs will continue to grow during the five years of this plan, and that the resulting benefits to NASA's programmatic objectives will continue to increase. Growing independent and, in some cases, competitive capabilities abroad require that we carefully assess U.S. interests before committing to specific cooperative projects. However, those increasing capabilities can make foreign agencies even more competent and reliable partners. Both the cooperative trends and the independent trends reflect foreign recognition of the utility of space technology for basic research and applications, rapid growth in foreign investment in government space programs and related commercial activities, and continuing recognition in the United States that carefully structured cooperation with other countries can both complement and supplement NASA's program activities. Areas in which growth in NASA cooperation with other countries may be most significant during the next five years are discussed below.

### 1. Cooperative Activities

#### a. Space Shuttle and Spacelab

International interest in using the Shuttle and Spacelab could continue to grow during the early 1980s as those systems become operational. Foreign agencies may enter into cooperative programs with us to develop and use Shuttle-based multiuser instruments for such activities as solar studies, plasma studies, and materials processing research. Also, they likely will supplement their cooperative programs with us by increasing their reimbursable use of the Shuttle, Spacelab, and multiuser instruments to support the objectives of their scientific and applications programs.

#### b. Space Applications

##### (1) Remote Sensing

Current widespread interest and participation in the U.S. program for remote sensing of land resources will continue to grow to the point where, by the mid-1980s, some fifteen foreign countries will be funding and operating stations to receive, process, and distribute Landsat satellite data. As the Landsat system approaches full operational status under the direction of the National Oceanic and Atmospheric Administration (NOAA) in the late 1980s, those international relationships are expected to continue. As other countries carry out their plans to develop independent remote sensing systems, NASA and NOAA will discuss with them prospects for making their systems compatible with and complementary to U.S. systems in order to enhance satellite remote sensing capabilities available to users throughout the world, including U.S. users. Cooperative participation in other NASA experimental remote sensing programs, such as those for atmospheric and ocean observations, could also expand during the years ahead.

## (2) Geodynamics

The global nature of geodynamics offers the prospect of considerable international cooperation. By the early 1980s, we are likely to have entered into a number of joint efforts related to crustal dynamics and earthquake research with scientific organizations in Asia, Australia, Latin America, and Europe for exchange of data and for sites for laser ranging and very long base-line interferometry installations.

## (3) Materials Processing

Discussions are under way with Western Europe, particularly Germany, to develop joint research projects in materials processing. Possible areas for cooperation are the sharing of flight opportunities and the development of facilities such as furnaces that are useful for a variety of experiments. Continued U.S. and foreign investments in materials processing research may lead to cooperative projects in areas where the proprietary and commercial interests of both sides can be adequately protected.

## (4) Communications

Participation by Canada, France, and the USSR in NASA's satellite-aided search and rescue demonstration project should be under way in 1982. Several other countries, including Japan and Norway, may also join in. We expect to develop other cooperative projects in communications research areas that will be of mutual benefit and not require transfer of critical U.S. technology.

## c. Space Science

### (1) Astrophysics

The European Space Agency (ESA) is providing solar arrays and the faint-object camera for the Space Telescope in return for a portion of the observing time on the Telescope after its planned launch in 1983. NASA is also cooperating with the Netherlands and the United Kingdom in developing and launching the Infrared Astronomy Satellite in 1981. We are actively pursuing possibilities for additional cooperative programs, particularly in astrophysics satellites of the Explorer class.

### (2) Planetary Research

The German Ministry for Research and Technology is providing the retropropulsion module and some scientific investigations for our Galileo mission, which is scheduled for launch to Jupiter in 1984. In addition, NASA and ESA are studying possible joint comet and lunar missions.

### (3) Solar Terrestrial

NASA and ESA are well into development of the International Solar Polar Mission, which will provide the first opportunity to explore solar and interplanetary phenomena from spacecraft traveling over the poles of the Sun. Development should soon start on the Active Magnetospheric Particle Tracer Explorer, a project we plan to conduct jointly with the German Ministry for Science and Technology, with each side providing a spacecraft. Canadian and European scientists are cooperating with us in planning the Origins of Plasma in Earth's Neighborhood program. One or more international cooperative projects in the 1980s are likely to result.

#### d. Solar Energy

Photovoltaic cell arrays show promise as a source of electrical power to provide essential services, such as pumping water and grinding grain, to remote communities that have no other sources of power readily available. NASA, with funding support from the Department of Energy and the Agency for International Development, is developing demonstration projects to be evaluated for such applications. We will conduct those demonstration projects primarily in developing countries, with the active participation of the host country in all phases of the projects.

#### e. Soviet Union

Cooperative exchanges are likely between a Soviet Venus mission in 1984 and the U.S. Venus Orbiting Imaging Radar mission planned for 1986. The United States may fly experiments on the next series of Soviet biological satellites (with primates) during the 1981-1985 period. In exchange, Soviet life sciences experiments may fly on a Shuttle-Spacelab mission planned for the same period. Exchanges will continue of data on and analyses of the effects of prolonged weightlessness on living organisms, including humans. As noted above, the Soviets are expected to begin in 1982 to participate with the United States, Canada, and France in a demonstration of a satellite-aided search and rescue system for ships and aircraft in distress.

#### f. China

Space relationships with China are expected to continue to develop on the basis of the January 1979 Understanding. U.S. industry is actively discussing with the Chinese their proposed procurement of a broadcasting and communications satellite system, including associated ground equipment, which could become operational in 1983 or 1984. A Landsat Memorandum of Understanding, recently concluded between NASA and the Chinese Academy of Sciences, cleared the way for establishment of a Chinese Landsat ground station. That station could become operational in 1982. A variety of other possibilities for future cooperation are being explored.

### 2. Reimbursable Launchings

Foreign countries and international organizations plan to launch about 15 to 18 geostationary communications satellites during the 1981-1985 period. In addition, 2 to 3 predominantly foreign Spacelab missions in 1983 and 1985 appear likely. With regard to smaller, simpler payloads, we have commitments from foreign industrial firms, educational institutions, and individuals for flight of nearly 70 Small Self-Contained Payloads, the type of payloads formerly called Get-Away Specials.

### 3. Competition and Cooperation

During the period of this plan, foreign competition is likely to grow, especially in remote sensing, communications, launch systems, and aeronautics. France and Japan are already developing remote sensing satellites, and Western Europe and Japan are developing satellites and ground systems for communications. Western Europe's Ariane booster, successfully tested in December 1979, will compete with the Shuttle as a launcher for some geostationary payloads. Western

Europe's A300-series wide-body commercial transport aircraft is successfully competing with U.S. wide-body transports in the world market. Western European general aviation and rotorcraft aircraft are achieving similar success. As in other fields, however, competition and cooperation are expected to proceed in parallel.

#### F. Schedules and Milestones

Table 6 presents a chronological list of the significant events that are connected with or will result from the NASA program described in this report.

Table 7 tabulates the estimated launchings of the Shuttle and its payloads, including Spacelab, and displays the estimated number of Shuttle orbiters that are expected to be in service each year from 1980 through 1985.

#### G. Funding Required

Figure 8 shows the funding required for the program described in this plan. The funding trends apparent on the figure show the effects of the major goals described on pages 3, 4, and 5.

Funding for the Shuttle decreases rapidly as Shuttle development approaches completion and production of the complete fleet progresses. Need for improvement of the Shuttle and extension of its initial capabilities are already recognized, and more will be discovered as we gain experience from operating it. Some funding for those purposes is included in the Shuttle DDT&E and Production funding.

Space Transportation funding increases somewhat in 1981 and 1982 as the Shuttle makes more space activity possible, and then becomes approximately level.

The need for starting several space engineering projects during the 1982-1985 period is apparent, and the funding for those projects is represented by the area labeled Space Systems Engineering.

In accordance with the President's Space Policy and the major goals of the Agency, the funding for applications grows rapidly. Funding for aeronautics, space technology, and space science also grows, but at a slower rate.

TABLE 6 -- SIGNIFICANT EVENTS

1980

Completion of Proof-of-Concept Flight Tests of Quiet Short-Haul Research Aircraft and Tilt-Rotor Research Aircraft  
 First Flight of Medium Primary Composite Structures for Commercial Transport Aircraft  
 Launch of Solar Maximum Mission to Measure Solar Activity  
 Launch of Measurement of Air Pollution from Shuttle  
 Completion of World Atlas 1 (Global Geologic Maps Based on Landsat Multispectral Imagery)  
 Completion of Global Survey of Earth's Magnetic Field with Magsat  
 Completion of Demonstration of Feasibility of Using Global Positioning System Radio Emissions for Geodetic Measurements  
 Initiation of Measurements of Relative Motion of North American, Pacific, and Australian Tectonic Plates  
 Initiation of Measurements of Intraplate Deformation of North American Tectonic Plate  
 Availability of First Space Shuttle  
 First Flight of Space Transportation System

1981

Completion of Modification of 40X80-Foot Wind Tunnel at Ames Research Center to Increase Airflow Speed and Add 80X120-Foot Test Section  
 Completion of Component Improvements for Reduced Fuel Consumption in Current Engines for Commercial Transport Aircraft  
 Launch of Infrared Astronomy Satellite to Carry out First Infrared Sky Survey  
 Voyager 2 Encounter with Saturn and Titan  
 Launch of Dynamics Explorer  
 Voyager 1 Encounter with Saturn and Titan  
 Launch of Solar Mesosphere Explorer  
 First Flight of Large Format Camera  
 Initiation of Data Acquisition by Thematic Mapper on Landsat-D, Providing Improved Spatial and Spectral Resolution and Broadened Spectral Coverage  
 U.S. Department of Agriculture Decision on Development of Operational Capability  
 Expansion of Measurements of Relative Motion of Tectonic Plates to Include Eurasian Plate  
 Launch of OSTA-1 Pallet on Shuttle  
 First Operational Flight of Space Transportation System  
 Availability of Inertial Upper Stage for Titan  
 Availability of Atlas-Class and Delta-Class Spinning Solid Upper Stages

TABLE 6 -- SIGNIFICANT EVENTS (CONTINUED)

1982

National Transonic Facility (Wind Tunnel) at Langley Research Center  
Operational  
Launch of OSS-1 Pallet on Shuttle  
Launch of Spacelab 1  
Launch of Stratospheric Aerosol and Gas Experiment  
Launch of Earth Radiation Budget Satellite-A  
Launch of Halogen Occultation Experiment  
Launch of Atmospheric Trace Molecules Observed by Spectroscopy  
Launch of Atmospheric Cloud Physics Laboratory  
Decision Between Global Positioning System and Spaceborne Geodynamics  
Ranging System for Monitoring Local Deformation  
Launch of Landsat-D' Equipped with Thematic Mapper and Multispectral  
Scanner  
Launch of MPS-1 (Materials Processing Pallet on Shuttle)  
Launch of Materials Experiment Assembly  
Reflight of OSTA-1 Payloads on Shuttle  
Deployment of Solar Electric Propulsion System Solar Array from Shuttle  
Flight Test of Auxiliary Ion Engine  
Availability of Second Space Shuttle  
Availability of Inertial Upper Stage for Shuttle  
Launch of First Satellite of Tracking and Data Relay Satellite System

1983

Completion of Initial Series of Tests of Components for Full-Scale  
Advanced Commercial Engines  
Launch of Active Magnetospheric Particle Tracer Explorer  
Launch of Chemical Release Facility  
Launch of OSS-2 Pallet on Shuttle  
Launch of Spacelab 2 (Astrophysics and Solar Physics Mission)  
Launch of OSTA-2 (Solar Electric Propulsion System and Materials Processing)  
on Shuttle  
Launch of Long-Duration Exposure Facility for Experiments in Space  
Launch, on Spacelab, of Variable Depression Angle Antenna for SIR-A  
Launch of MPS-2 (Materials Processing Pallet on Shuttle)  
Launch of Spacelab 3 (Low-Gravity Mission)

1984

Completion of Test of Integrated Core-Low Spool System for Energy Efficient  
Engine  
Launch of Space Telescope (First Permanent Observatory in Space)  
Launch of Galileo Mission to Orbit Jupiter and Probe Its Atmosphere  
(with Powered Flyby of Mars)  
Launch of OSS-3 Pallet on Shuttle  
Launch of Spacelab 4 (Life Sciences Mission)  
Launch of Spacelab 5 (Astrophysics Mission)  
Launch of Spacelab 6 (Solar Terrestrial Mission)

TABLE 6 -- SIGNIFICANT EVENTS (CONTINUED)

1984 (CONTINUED)

Launch of Landsat-D"  
Launch on Spacelab of Multiband Thermal Imager, Gravity Gradiometer,  
Global Time Transfer Experiment, and Dual Frequency, Multipolarization  
Synthetic Aperture Radar  
Launch of OSTA-3 (Earth Observation)  
Launch of Spacelab 7 (Earth Observation Mission)  
Launch of MPS-3 (Materials Processing Pallet on Shuttle)  
Retrieval of Long-Duration Exposure Facility from Space  
Completion of Initial Orbiter Experiments Flight Program  
Demonstration of Initial Total NASA End-to-End Data System  
Availability of Third Space Shuttle  
Availability of Inertial Upper Stage for Planetary Spacecraft  
Initial Operation of Power Extension Package  
Completion of Shuttle Facilities at Vandenberg Air Force Base  
Tracking and Data Relay Satellite System Operational

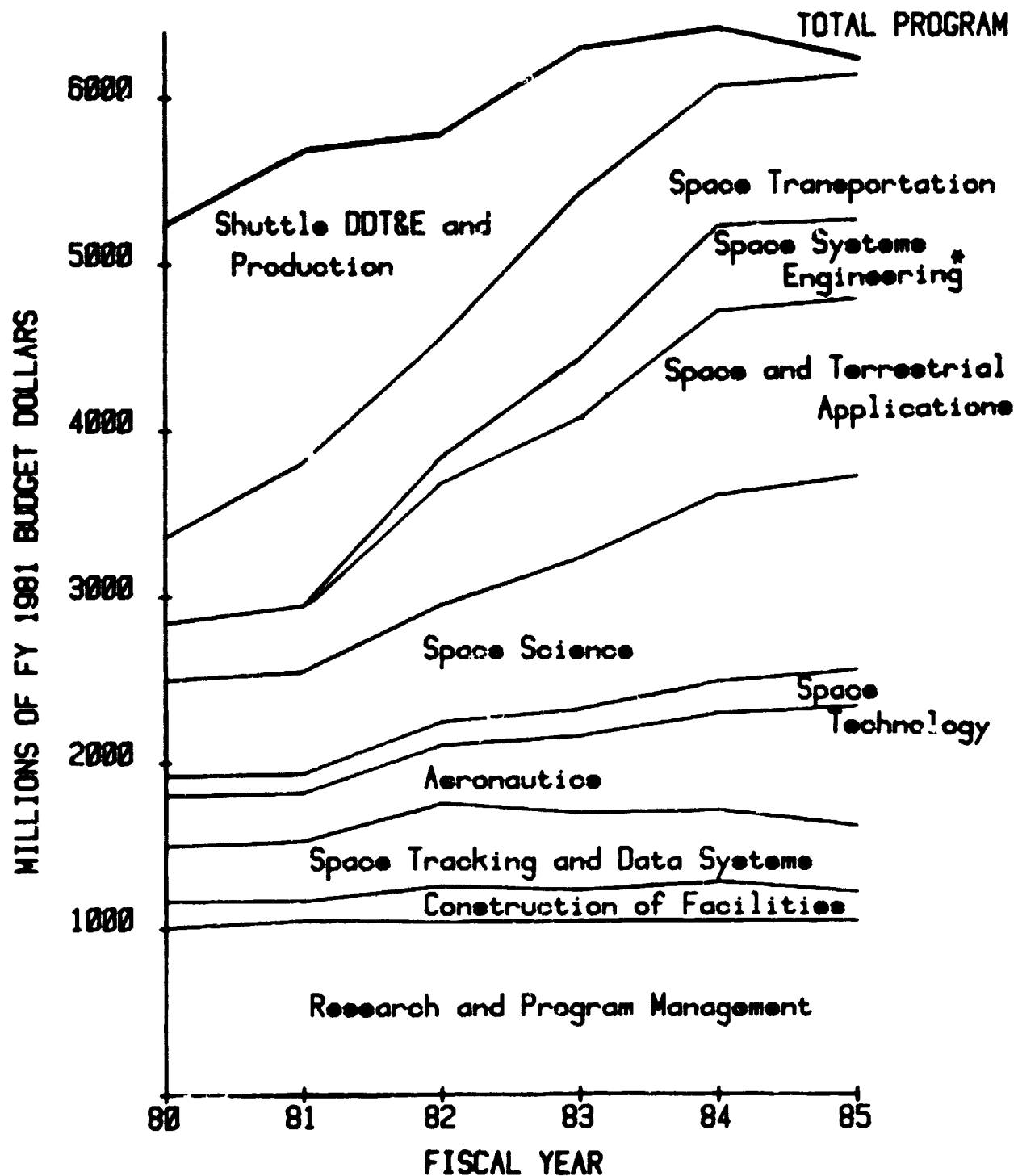
1985

Completion of Low-Speed Ground Tests of Advanced Turboprop Propulsion  
System  
Launch of Gamma Ray Observatory  
Launch of Cosmic Background Explorer  
Launch of Extreme Ultraviolet Explorer  
Launch of Halley Flyby Mission  
Launch of International Solar Polar Mission (First Spacecraft That  
Will Fly Over Sun's Poles)  
Launch of Solar Optical Telescope  
Launch of Origins of Plasma in Earth's Neighborhood Mission  
Launch of OSS-4 and OSS-5 Pallets on Shuttle  
Launch of Spacelab 9 (Astrophysics Mission)  
Launch of Spacelab 10 (Life Sciences Mission)  
Launch of Spacelab 11 (Space Plasma Mission)  
Launch of Upper Atmosphere Research Satellites  
Completion of AgRISTARS Program  
Expansion of Measurements of Relative Motion of Tectonic Plates to  
Include African, South American, and Several Minor Plates  
Launch of OSTA-4 (Materials Experiment Assembly 2)  
Launch of Spacelab 8 (Materials Processing Mission)  
Launch of Spacelab-12 (Earth Observation Mission)  
Launch of MPS-4 (Materials Processing Pallet on Shuttle)  
Launch of Spacelab 13 (Materials Processing Mission)  
Initial Operation of Satellite Services near Orbiter  
Initial Operation of 25-kW Power System  
Availability of Fourth Space Shuttle

TABLE 7 -- ESTIMATED SHUTTLE FLIGHTS

	1980	1981	1982	1983	1984	1985
Orbital Flight Test Flights (NASA)	1	3				
Spacelab Flights						
NASA			1	3	5	5
Foreign			$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{6}$
Total			$\frac{2}{2}$	$\frac{3}{3}$	$\frac{5}{6}$	$\frac{5}{6}$
Automated Payloads (Free-Flying Spacecraft)						
NASA				3	5	5
Other U.S. Government Agencies (non-DOD)				-	2	2
U.S. Commercial			2	3	3	3
Foreign			-	1	1	2
Department of Defense (DOD)			$\frac{1}{3}$	$\frac{3}{3}$	$\frac{1}{2}$	9
Total			$\frac{3}{3}$	10	12	21
Total Launches						
NASA	1	3	1	6	10	10
Other U.S. Government Agencies (non-DOD)			-	-	2	2
U.S. Commercial			2	3	3	3
Foreign			1	1	2	3
Department of Defense (DOD)			1	3	1	9
Reflights			-	1	1	3
Total	1	3	5	14	19	30
Shuttles Available (Shuttle-years)	0.3	1.0	1.1	2.0	2.8	3.6

FIGURE 8.  
NASA PROGRAM FUNDING



\*Does not include funding for Interim Orbital Transfer Vehicle (IOTV) in FY 1983 and for IOTV, Geostationary Platform Demonstration, and Geostationary Satellite Servicer in FY 1984 and 1985.

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### III. AERONAUTICS PROGRAM

Aviation is important to the United States as a mode of transportation, as an element in national defense, and as a source of economic strength. The United States dominates the Free-World marketplace in transport and military aircraft and holds a leading position in other types of aircraft. Continued preeminence in aviation will demand progressive advances in the Nation's aircraft and system capabilities, in the productivity and profitability of the U.S. aviation industry, and in the environmental acceptability of U.S. aircraft. Growth of air travel, which is forecast to increase by a factor of three to four by the year 2000, and rising foreign competition in world aircraft markets cause the maintenance of U.S. technological leadership to be a matter of urgent national importance and concern.

#### A. NASA's Roles

NASA's roles in aeronautics are, by charter, to improve the usefulness, performance, speed, safety, and efficiency of U.S. civil and military aeronautical vehicles and to preserve U.S. leadership in aeronautical science and technology and the application thereof. To fill those roles, NASA has oriented its aeronautics research and technology program to meet the near-term and far-term technology needs of the aviation industry, aircraft operators, government regulatory agencies, and the Department of Defense. NASA coordinates closely with each of those components of the aeronautics community in defining technology needs and the objectives for its aeronautics program. NASA technology has influenced the design of virtually every civil and military airplane built in the United States.

#### B. Program Goal

The goal of NASA's Aeronautics program is to generate technology required for:

- o Safer, more economical, efficient, fuel-conservative, and environmentally acceptable air transportation systems to satisfy current and projected national needs
- o Assurance that the United States will maintain its competitive position in the international aviation marketplace
- o Maintenance of the superiority of the Nation's current and future military aircraft.

#### C. Planning Assumptions

The NASA Aeronautics program is based on the following fundamental assumptions regarding needs and responsibilities:

- o Energy availability will continue to be a serious problem, creating a demand for advanced, fuel-efficient aircraft capable of operating on broadened property hydrocarbon fuels.

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- o Air transportation of passengers and cargo will continue to expand, creating demands for new transport aircraft in many sizes.
- o The rate of growth in the use of helicopters and general-aviation aircraft and in the movement of cargo by air will continue to be higher than the rate of growth in commercial air passenger travel.
- o Continued improvement in environmental acceptability of aviation will persist as a national concern.
- o The unique characteristics of supersonic, short-takeoff-and-landing, and vertical-takeoff-and-landing aircraft and the latent demand for the transportation services they can provide will eventually justify their development for both civil and military use.
- o NASA, as the Nation's primary agent for civil aeronautics research and technology, will continue to be depended on for technological support to aircraft developers, producers, and operators; to regulatory agencies; and to the Department of Defense.

#### D. Program Elements

The Aeronautics program consists of both a core of fundamental research and technology (R&T) in essential technical disciplines and a wide variety of focused, systems-oriented activities directly applicable to individual classes of aircraft. The fundamental R&T builds the foundation upon which future aeronautical advances are developed. The focused research is, for the most part, directed at ensuring the readiness of technology and the reduction to practice of aeronautics advances specifically tailored to needed aeronautical systems. When high development risk is recognized as a potential deterrent to incorporation of important technical advances into systems, NASA may extend its focused program to include demonstration of the technology involved. The focused, systems-oriented research also includes investigation of advanced concepts and determination of their technology requirements.

Preparing long-lead technologies and ensuring their timely readiness require use of the best available advice and research capabilities in the university-industry-government community. Advisory committees and select boards composed of recognized experts in all aeronautics disciplines and application areas strongly influence our selection of major directions for our research. We also coordinate our aeronautics activities with other agencies, particularly the Department of Defense and the Federal Aviation Administration.

#### E. Program Content

##### 1. Fundamental R&T

NASA's fundamental R&T consists of continuing research in individual technical disciplines that are broadly applicable to many, frequently all, classes of aircraft. Those disciplines include aerodynamics, materials and structures, propulsion, and avionics and human factors. Challenging opportunities are present for dramatic innovations in each of those disciplines and for integrating the disciplines for effective application to flight systems.

The principal thrust of the fundamental R&T is far term and consists of exploring future possibilities and developing ideas that will lead to the aeronautics technology of the future. The program involves hundreds of important programs and thousands of individual research tasks. A select sample is described below.

#### a. Aerodynamics

With its worldwide preeminence and reputation in aerodynamics, NASA has a unique role as the only U.S. Government agency with responsibility and capability for carrying out advanced aerodynamics R&T. Because the aircraft industry depends heavily on NASA for basic technological support, that primary responsibility for aerodynamics R&T will remain unchanged. Thus, NASA will continue to be concerned with generic aerodynamics to provide the broadly applicable data, analyses, concepts, and approaches required for more specialized vehicle-specific aerodynamics programs. Two primary areas we will pursue during the next five years are computational fluid dynamics and advanced testing techniques.

The goal of our program in computational fluid dynamics is to develop capabilities for calculating accurately the flight characteristics of complete aircraft. To achieve this goal, we will focus our efforts during the next five years on developing advanced numerical techniques, special-purpose data processors, and models for simulating turbulence.

Although the NASA-led developments in computational aerodynamics are expected to reduce the amount of wind-tunnel testing, the demands on wind-tunnel tests from the standpoint of data quality and detail will increase. Hence, during the 1981-1985 period, we will maintain a major R&T program to continue developing technology for wind-tunnel testing. Recently developed technology for cryogenic wind tunnels has enhanced our ability to achieve flight simulation closer to flight Reynolds numbers and has led to the National Transonic Facility currently under construction and scheduled for operation in early 1982.

Anticipated developments and improvements during the 1981-1985 period in aerodynamics analysis, test, and design tools will make possible significant advances in aircraft performance and efficiency. We will actively pursue significant reduction of turbulent drag, optimization of multi-element airfoils, better integration of propulsion and other aircraft systems, and minimization of wake-vortex turbulence.

#### b. Materials and Structures

NASA's Materials and Structures program will provide technology that will permit the aerospace industry to develop new and improved, safe and reliable metals, polymers, and ceramics and to use them in advanced structures. Our technology development for materials will emphasize composites as strong, lightweight structural materials for airframes. We also will continue programs to improve our ability to understand and predict the mechanisms that limit the lifetimes of materials, as well as programs to replace scarce or potentially scarce metals, such as cobalt and chromium, in high-temperature, corrosion-resistant alloys for jet engines.

Our structures programs will seek to provide technology for future development of high-temperature structures required for hypersonic flight. We will continue research on dynamics, loads, and aeroelasticity to provide improved methods for determining analytically the structural response and stability of aeronautical systems. We will use the resulting analytical models in multidisciplinary, computer-aided evaluation and design of aerodynamically advanced vehicles and propulsion system components.

Work related to technology for engine hot sections will begin in 1981 and will concentrate on materials and processes to provide higher performance and longer life. These advances in fundamental technologies will be tested in components and engine systems.

#### c. Propulsion

NASA's Propulsion R&T program consists of multidisciplinary research activities focused on development of technology to improve the efficiency, reliability, durability, and safety of propulsion systems for future aircraft, and to reduce the systems' energy consumption, operating costs, and noise and emission levels. The program encompasses basic research in such areas as computational fluid dynamics, heat transfer, tribology, combustion kinetics, controls, and acoustics, as well as exploratory research and technology development for advanced components and subsystems such as fans, compressors, turbines, combustors, and other mechanical components. We plan to increase our development of technology related to alternative aircraft fuels and of components for engine and fuel systems that will permit aircraft to use fuels with a wide range of properties and combustion characteristics. This program will continue to provide advanced technology supporting improvement of propulsion systems for all types of aircraft ranging from small general-aviation aircraft and helicopters to commercial transports and military aircraft. The program will also continue to provide a technology base in noise and emissions for use by the Government in establishing aircraft environmental regulations.

#### d. Avionics and Human Factors

The objectives of the Avionics and Human Factors program are to increase flight safety, improve aircraft efficiency, and reduce the cost of aircraft by developing flight-control and information systems that realistically consider the capabilities and limitations of flight-crew members. We are developing advanced control and design techniques to provide ultra-high reliability, particularly during crucial flight situations. To improve cockpit systems, reduce crew workload, and improve the interface between the flight crew and the air traffic control system, we are developing guidelines for defining the electronics and human-factor features of crew-station design.

### 2. Focused, Systems-Oriented Research

NASA's focused research in aeronautics involves application of all the fundamental R&T disciplines to the unique requirements of the following specific classes of aircraft: transport (subsonic, conventional takeoff and landing), general aviation, low-speed (rotorcraft, vertical and short takeoff and landing, and lighter than air), and high-speed (high-performance and supersonic cruise).

#### a. Transport Aircraft

NASA's focused research for transport aircraft includes the Aircraft Energy Efficiency (ACEE) program, as well as several other specific programs to improve the safety and operational efficiency of subsonic transports and to minimize their adverse environmental effects.

##### (1) ACEE Program

The highlights of the ACEE program will be the successful completion in 1981 of the Engine Component Improvement program and of the first phase of the Advanced Turboprop Program (ATP). Phase II of ATP will begin in 1981 and will continue through 1985, when the flight demonstrations comprising Phase III will begin. Technology development for the Energy Efficient Engine will continue into 1984 and for aerodynamics and active controls for energy efficient transports through 1982. Research on composite structures will continue until its completion in 1983. A new initiative to explore the applications of composites technology to large primary structures will begin in 1982. Flight and wind-tunnel tests of laminar flow control concepts will continue and may lead to subsequent flight validation of full-scale systems.

##### (2) Non-ACEE Program

In addition to continuing the momentum of the ACEE program, this plan sustains development of propulsion technology, augments research on critical flight operations and safety, emphasizes avionics and controls during the last four years of the planning period, and augments earlier exploratory studies of small commuter transports, large cargo aircraft, and cryogenic-fueled vehicles.

Technology development for advanced commercial engines will begin in 1982 and will address key technical barriers to major improvements in future engines.

Aircraft safety work will continue through the planning period. We will complete in 1981 Phase I of the Fire Resistant Materials Engineering (FIREMEN) program and our evaluation of concepts for instrumentation for lightning research. Phase II of the FIREMEN program and accelerated development of technology related to lightning hazards will begin in 1982. Augmentations of the safety program in 1982 will also include detailed investigation of icing problems and broad-based research in structures to improve the crashworthiness of transport aircraft.

Development of technology to improve avionics systems and increase the operating efficiency of transport aircraft in advanced air traffic control environments will continue through 1981 in the Terminal Configured Vehicles (TCV) program. In 1982, it will be augmented with the Advanced TCV Technology Readiness program. Two new activities will be initiated in 1983; namely, Active Controls Technology for Transports and Avionics and Controls Integration Technology. The remaining activities in the non-ACEE part of the Transport Aircraft program will be Phase I activity in 1982 in the Small Transport Aircraft Technology program, which will concentrate on identifying the most promising technology options to be addressed in Phase II, and development of systems technology for large cargo aircraft starting in 1982, for cryogenic-fueled aircraft in 1983, and for terminal systems for cryogenic-fueled aircraft in 1984.

## **b. General Aviation**

This program emphasizes efficient aerodynamics to reduce drag; avionics and systems characteristics to improve single-pilot instrument flight; efficient, low-noise propulsion systems; and aircraft safety with regard to stall and spin characteristics and to the crashworthiness of aircraft structures. We will initiate in 1982 development of technology that industry needs for use in developing improved, low-noise, high-efficiency propellers; efficient, affordable, low-horsepower turboprop engines; spark-ignition and diesel internal combustion engines with greater fuel efficiency; simplified and integrated general-aviation communications, navigation, and control avionics, with emphasis on their compatibility with the air traffic control system and on reduction in single-pilot workloads; wings with natural laminar flow; aerodynamically integrated dispersal systems for aerial application of insecticides, fertilizers, and other materials; and design concepts and design methods specifically applicable to general-aviation needs and cost constraints.

## **c. Low-Speed Aircraft**

### **(1) Rotorcraft**

We will continue our program to develop an R&T base for rotorcraft dynamics, aerodynamics, avionics components, flying quality, and flight evaluation of selected airframe components fabricated from composite materials. Flight research on operating systems will start with the Tilt Rotor Research Aircraft (XV-15). Flights in 1982 with the Rotor Systems Research Aircraft to test rotor-systems technology will soon follow, and ground-based testing of helicopter transmission systems will continue our research in that area.

In 1981, we will augment the Advanced Rotorcraft Technology program that we initiated this year to develop and verify design methods for advanced rotorcraft. Our early emphasis will be on predicting the aerodynamics of isolated rotors and rotor-airframe assemblies, and on developing analysis techniques for predicting the noise that new designs of rotorcraft will create.

The program will include research on unique problems related to small engines for rotorcraft, including concepts for convertible drives. Because use of helicopters is increasing, we will increase our work related to their all-weather operations. We will conduct initial studies and selected ground-based and flight tests relating to concepts for high-speed flight and to unique problems of large rotorcraft.

Later phases of our Rotorcraft program will focus on technology for the use of composite materials in airframes, with emphasis on primary structures. Other subjects to be researched include rotorcraft operations in the high-density traffic at air terminals, techniques for mixing helicopter operations efficiently with the operation of fixed-wing aircraft, and reduction of vibrations by use of advanced active-control techniques. As that research work progresses, we will shift our emphasis to integration of systems such as propulsion and flight-control systems, and to hardware experiments to verify analysis methods developed in the earlier phases of the program.

## (2) Vertical and Short Takeoff and Landing (V/STOL) Aircraft

NASA's STOL program is relatively mature. During the 1981-1985 planning period, it will consist only of flight experiments, primarily with the Quiet Short-Haul Research Aircraft, to establish for powered-lift aircraft a technology base providing design and certification criteria for future short-haul transport aircraft.

Our V/STOL program is considerably less mature. Although it will continue to receive only a low level of effort, it will consist of several activities needed for building a technology base. A program to be initiated in 1982, V/STOL Propulsion Systems Technology, will provide modular, ground-based equipment that will demonstrate technology for propulsion systems for subsonic V/STOL aircraft and validate technology for integrated controls and several V/STOL propulsion concepts that appear promising. Augmentation of our Flight Systems Technology program in 1983 will provide for development of a modern facility to simulate VTOL flight and for evaluation, over several years, of simulated V/STOL aircraft and flight systems. In 1984, we will augment our V/STOL Technology Integration program so that we can resolve key technology problems associated with environmental factors, flight-path management, and integration of propulsion systems with airframes. Another augmentation in 1985 will provide the means for acquiring a ground-based technology demonstrator with which we will start validating technology for V/STOL propulsion system concepts.

### d. High-Speed Aircraft

#### (1) High-Performance Aircraft

The programs for this class of aircraft will focus on improving the performance and effectiveness of high-performance aircraft and missiles. We will conduct a strong basic research and technology development program to provide new concepts and technologies for the far-term future.

Work initiated in preceding years will continue in 1981. The major experimental program will be the Highly Maneuverable Aircraft Technology (HiMAT) program, with completion of the basic flight program scheduled for late 1981. Specific NASA flight experiments investigating the angle-of-attack characteristics of the F-14 will commence in 1980 based on the joint testing NASA and the Navy conducted in 1979. Studies connected with integration of engine and airframe control systems will continue into 1981. As part of the Air Force's Advanced Technology Fighter Integration program, NASA and the Air Force will initiate joint flight research in the current Mission Adaptive Wing program.

Near-term new activities will concentrate on selective advanced technology flight experiments. NASA, the Navy, and the Air Force will jointly conduct flight research on a current high-performance aircraft modified to accommodate the Navy-developed Augmented Deflector Exhaust Nozzle. Also, NASA will modify the HiMAT vehicles to continue flight research related to very advanced, high-risk technology and will flight test an advanced decoupler pylon that is expected to dramatically alleviate the problem of flutter of munitions stores on high-performance aircraft.

## (2) Supersonic Cruise

Our Supersonic Cruise research program will continue to study major technical problems inherent in advanced military and civil aircraft of this class. Those problems are all related to integration of advanced technologies and optimization for fuel efficiency, operating economics, and environmental acceptability. Our current program addresses the integration of systems; the discipline technologies of aerodynamics, structures, and materials; and the interactions between propulsion systems and airframes.

Our Variable Cycle Engine program continues to focus on development and demonstration of critical technologies for components unique to that advanced propulsion system. The augmentation provided by Congress in 1980 and the one we plan for 1981 will continue that work, with emphasis on advanced techniques for modulating the flow through the engines and for suppressing the noise generated. We will conduct a system demonstration to verify the performance of critical components and systems, including substantiation of the system's aerodynamic and acoustic performance in a forward velocity field.

Our long-range planning for Supersonic Cruise Transport (SST) aircraft is more highly structured than it formerly was as a result of a request from the House Committee on Science and Technology. Our response to the Committee's request was a report entitled Potential Future Initiative Directions in NASA Aeronautics Programs, August 1979. SSTs are a major element of that report; and the report identifies the activities planned and their cost and phasing over an 8-year period, including the 1981 augmentation of the Variable Cycle Engine technology program mentioned in the preceding paragraph.

We plan to start four new activities in 1982 in anticipation of inclusion of a strong endorsement for increasing this nation's SST technology efforts in a report, Impact of Advanced Air Transport Technology: Advanced High Speed Aircraft, to be published in April 1980 by the Congressional Office of Technology Assessment. Those four activities include three programs -- Advanced Core Technology, Nacelle-Airframe Integration Technology, and High-Speed Aircraft Structures Technology -- and a study, High-Speed Research Aircraft Definition Study, to address the persistent and controversial question of what means and approach should be used to perform inflight research.

Our plans for 1983 provide for initiation of a program, Supersonic Cruise Technology Validation, which will follow, in general, the outline of a report, A Technology Validation Program Leading to Potential Technology Readiness Options for an Advanced Supersonic Transport, prepared at the request of the U. S. House of Representatives in September 1978. Initiation of that program must be preceded by initiation of the three programs planned for initiation in 1982 mentioned in the previous paragraph.

Our plan also includes a 1984 initiative, Variable Cycle Experimental Engine(s), which will complement the Supersonic Cruise Technology Validation program.

**F. Schedule and Funding**

Table 8 shows the phasing of the Aeronautics program and Figure 9 shows the program's funding requirements.

TABLE 8 -- AERONAUTICS PROGRAM SCHEDULE

PROGRAM	RESPONSIBLE FIELD CENTERS *	PROGRAM PHASE		ADDITIONAL IMPORTANT DATES
		INITIA- TION	COMPLE- TION	
<u>FUNDAMENTAL R&amp;T</u>				
Hot Section Technology	LeRC	1981	1985	Development of cyclic constitutive behavior model --1983; environmental simulation model -- complete 1984
Avionics and Human Factors	ARC,DFRC, LaRC,LeRC, JSC	1982	--	Ultra-reliable controls concept -- define 1983; systems integration methodology -- complete 1985; human factors guidelines -- 1986; cockpit display of traffic information evaluations -- complete 1986; integrated cockpit avionics system -- develop 1987
Aircraft Technology for Future Fuels: Phase I	LeRC	1982	1986	Engine and fuel system component evaluations -- complete 1986
Phase II	LeRC	1985	--	
Numerical Aerodynamic Simulator	ARC	1982	--	Construction -- initiate 1984; acceptance tests -- initiate 1987
<u>TRANSPORT AIRCRAFT</u>				
<u>ACEE</u>				
Engine Component Improvement	LeRC	Ongoing	1981	
Energy Efficient Engine	LeRC	Ongoing	1984	
Advanced Turboprops, Phase I	LeRC	Ongoing	1981	Jet Star acoustic flight tests -- initiate 1980
Energy Efficient Transport	LaRC	Ongoing	1982	
Composite Primary Structures	LaRC	Ongoing	1983	Composite secondary structures -- complete 1981
Laminar Flow Control, Phase II	LaRC	Ongoing	1984	Leading edge glove flights -- complete 1984
Advanced Turboprops, Phase II	LeRC	1981	1985	Large-scale propeller structural dynamic evaluation -- initiate 1981
Advanced Turboprops, Phase III	LeRC	1985	1988	System integration and flight demonstration -- initiate 1985
Large Primary Composite Structures	LaRC	1982	1986	Critical component tests -- 1983; component fabrication -- 1985; component testing -- 1986
<u>Non-ACEE</u>				
Discipline Technology	ARC,DFRC	Ongoing	--	Digital fly-by-wire -- complete 1980; broadened property fuels -- complete 1983; stratospheric cruise emission reduction -- complete 1984
Terminal Configured Vehicle	LaRC	Ongoing	--	Cockpit displayed traffic information flights -- complete 1984

\* ARC = Ames Research Center  
DFRC = Dryden Flight Research Center  
JSC = Johnson Space Center

LaRC = Langley Research Center  
LeRC = Lewis Research Center

TABLE 8 -- AERONAUTICS PROGRAM SCHEDULE (CONTINUED)

PROGRAM	RESPONSIBLE FIELD CENTERS *	PROGRAM PHASE		ADDITIONAL IMPORTANT DATES
		INITIA- TION	COMPLE- TION	
<u>Non-ACEE (Continued)</u>				
Active Controls Technology for Transports	LaRC	1983	1989	Laboratory evaluation -- initiate 1986
Transport Avionics and Controls Integration Technology	LaRC, LeRC	1983	1990	System concept -- define 1985; first flight -- 1988
Advanced Transport Aircraft Technology	ARC, LaRC	1982	--	Small transport aircraft technology -- initiate 1982; large-cargo and cryogenic-fueled aircraft technology and transport crashworthiness -- initiate 1982
Advanced Commercial Engine	LeRC	1982	1986	Engine gas generator technology -- initiate 1982; full-scale rig performance -- complete 1984
<u>GENERAL AVIATION</u>				
Demonstration Advanced Avionics System (DAAS)	ARC	Ongoing	1982	System check-out in aircraft -- complete 1981; test DAAS -- flight test with Discrete Address Beacon System 1982; operational flight evaluation -- complete 1982; second-generation DAAS -- test 1985
General Aviation Propeller Technology	LeRC	1982	1986	Aerodynamics and acoustic screening tests -- complete 1983; composite and aeroelastic design -- complete 1984; ground tests -- complete 1985
General Aviation Turbine Engine	LeRC	1982	1986	Gas generator development -- initiate 1983; experimental engine -- initiate 1984
Internal Combustion Engine Systems	LeRC	1982	1986	Advanced engine development -- initiate 1984; near-term improvements -- demonstrate 1986
Avionics, Control, and Display Technology	LaRC	1982	1989	Approach and landing with Global Positioning System -- 1985; fluidic flight control system -- test 1985; natural laminar flow wing -- flight test 1984
Advanced Aerodynamics and Structures Technology	LaRC	1982	1986	Integrated aerial application system -- flight test 1985; composite structures methodology -- demonstrate 1986
<u>LOW-SPEED AIRCRAFT</u>				
<u>Rotorcraft</u>				
Rotor Systems	ARC	Ongoing	1984	Advanced rotor system flight test -- initiate 1981
Operating Systems	ARC	Ongoing	1984	XV-15 operating systems flight test -- initiate 1982

\* ARC = Ames Research Center  
 LaRC = Langley Research Center  
 LeRC = Lewis Research Center

TABLE 8 -- AERONAUTICS PROGRAM SCHEDULE (CONTINUED)

PROGRAM	RESPONSIBLE FIELD CENTERS *	PROGRAM PHASE		ADDITIONAL IMPORTANT DATES
		INITIA- TION	COMPLE- TION	
<u>Rotorcraft (Continued)</u>				
Helicopter Transmission Systems	LeRC	Ongoing	1983	500-HP traction-drive bench tests -- complete 1983
Advanced Rotorcraft Systems Technology:				
Aerodynamics	ARC	1981	1987	Ground-based verification tests -- initiate 1986
Propulsion	LeRC	1982	1988	Power-transfer system ground tests -- initiate 1983
Flight Control	ARC	1981	1989	Remote-site, all weather flight evaluations -- initiate 1981; high-density terminal-area operations simulation -- complete 1985
Structures	LaRC	1982	--	Major composite-fuselage components ground test -- initiate 1986
Vibration Reduction	ARC	1983	--	Initial assessment active-controls vibration reduction -- complete 1983
Advanced Vehicle Technology	ARC	1982	1988	Conceptual advanced high-speed vehicle assessment -- complete 1984; large rotorcraft systems ground-based evaluation -- complete 1987
<u>Vertical and Short Takeoff and Landing (V/STOL) Aircraft</u>				
Quiet Propulsive-Lift Systems Technology	ARC	Ongoing	1982	Quiet Short-Haul Research Aircraft flight experiments -- initiate 1980
V/STOL Experiments	LeRC	Ongoing	1982	Propulsion-simulation model test -- complete 1981
V/STOL Propulsion Systems Technology	LeRC	1982	1990	Full-scale propulsion demonstrator -- deliver 1985
V/STOL Flight Systems Technology	ARC	1983	1991	Inflight simulation -- initiate 1985
V/STOL Technology Integration	ARC	1984	1992	First integrated-model test -- complete 1986
V/STOL Supersonic Propulsion Systems Technology	LeRC	1985	1993	Ground-based technology demonstrator -- deliver 1988
<u>HIGH-SPEED AIRCRAFT</u>				
<u>High-Performance Aircraft</u>				
High Angle-of-Attack Experiment	DFRC	Ongoing	1981	F-14 high angle-of-attack research -- complete 1981
Highly Maneuverable Aircraft Technology (HiMAT)	DFRC	Ongoing	1981	
Engine-Airframe-Control Integration	DFRC	Ongoing	1986	Fully integrated control-system flight research -- initiate 1981

\* ARC = Ames Research Center  
DFRC = Dryden Flight Research Center

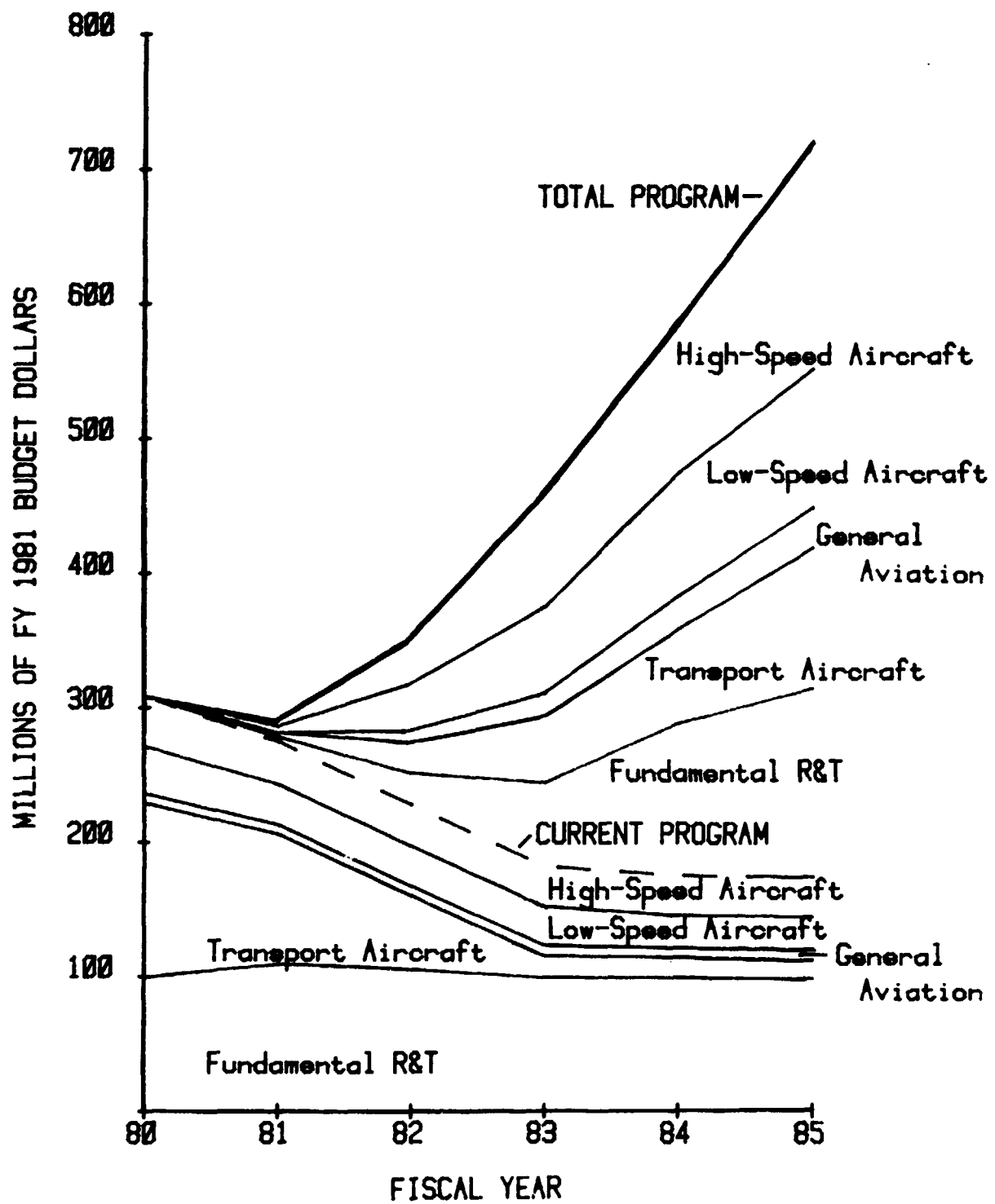
LaRC = Langley Research Center  
LeRC = Lewis Research Center

TABLE 8 -- AERONAUTICS PROGRAM SCHEDULE (CONTINUED)

PROGRAM	RESPONSIBLE FIELD CENTERS *	PROGRAM PHASE		ADDITIONAL IMPORTANT DATES
		INITIA- TION	COMPLE- TION	
<u>High-Performance Aircraft (Continued)</u>				
Mission Adaptive Wing	DFRC	Ongoing	1983	Flight test program -- initiate 1981
High-Performance Advanced Flight Experiments	DFRC	1982	1987	Joint NASA-Navy-Air Force 2-D nozzle flight experiment -- initiate 1982; HiMAT advanced aerodynamics experiment -- initiate 1982; decoupler-pylon flight research -- complete 1983
<u>Supersonic Cruise Aircraft</u>				
Discipline Technology	LaRC	Ongoing	--	Advanced large-scale airframe components test -- complete 1981
Variable Cycle Engine (VCE) Component Tests	LeRC	Ongoing	1980	
Propulsion Technologies:				
Variable Cycle Engine Technology	LeRC	1981	1985	Aerodynamics and acoustic performance in a forward velocity field -- demonstrate 1983; demonstration of critical low-speed technologies -- complete 1985
Advanced Core Technology	LeRC	1982	1986	Rig tests of advanced core components -- complete 1984; systems verification and limited endurance tests of core engine -- complete 1986
Variable Cycle Experimental Engine	LeRC	1984	1988	Total system performance and environmental compliance of variable cycle engine -- demonstrate 1988
Airframe Technologies:				
Nacelle-Airframe Integration	LeRC	1982	1986	Inlet concept -- select for testing 1983; inlet and VCE forward-swept velocity tests -- 1986
High-Speed Aircraft Structures Technology	LaRC	1982	1986	Fabrication of test structures -- initiate 1983; structural test program -- initiate 1984
Aircraft Systems Technology:				
High-Speed Aircraft Definition Study	LaRC	1982	1985	Competitive studies -- initiate 1982
Supersonic Cruise Technology Validation	LaRC	1983	1986	Design-cruise wind-tunnel tests -- complete 1983; inlet-nozzle interaction tests -- complete 1984; propulsion technology validation -- complete 1985; supersonic cruise technology validation -- complete 1986
High-Speed Research Aircraft	DFRC	--	--	

\* DFRC = Dryden Flight Research Center  
 LaRC = Langley Research Center  
 LeRC = Lewis Research Center

FIGURE 9.  
AERONAUTICS PROGRAM FUNDING



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#### IV. SPACE SCIENCE PROGRAM

As we enter the decade of the 1980s, we can look back at ten years of unparalleled achievement in mankind's attempts to explore the cosmos. From above Earth's atmosphere, we have seen the universe through new eyes. From the broad reaches of the solar system, we have seen the craters of Mercury, the mountains of Mars, and the moons of Jupiter. We have searched for life on the surface of Mars. Our understanding of Earth's local environment in space as well as its larger cosmic environment has been radically altered by the accomplishments of the Space Age.

Space science deals with the most fundamental questions we can ask about ourselves, our origins, and our destiny. Who are we? Where did we come from? Where are we going? Are we alone? Access to space has given us a new means for addressing these questions, and the accomplishments of the past have set the stage for the possibilities of the future.

This space science plan describes the major initiatives we propose to undertake in the next five years to obtain answers to such questions as those above. Also, because the process of planning and defining new missions and developing technology for those missions frequently requires a decade or more, this plan indicates, where appropriate, potential missions that go well beyond the 5-year period.

Although the description of the Space Science program that follows is organized by program element, the Space Science program is a unified one. The overall plan has been designed to make progress on a broad spectrum of scientific fronts ranging from the behavior of biological cells in the space environment to the ultimate fate of the universe.

##### A. Program Organization

The Space Science program consists of four major elements:

- o The Astrophysics program, which seeks to understand the origin and evolution of the universe, and to study and test the fundamental laws of physics that govern observed celestial phenomena
- o The Planetary program, which studies the origin, evolution, and current state of the solar system; investigates, by means of comparative study of solar system bodies, the past and present processes that affect the Earth and its environment; and studies the relation of the chemical history of the solar system to the origin and evolution of life
- o The Solar Terrestrial program, which studies the processes that generate energy in the Sun and transform and transport that energy to Earth, as well as the interactions of that energy with Earth's space environment and magnetic field
- o The Life Sciences program, which seeks to ensure the health, safety, well-being, and effective performance of humans in space; ultimately break human dependence on Earth's environment; use the space environment to further knowledge in medicine and biology; and understand the origin and distribution of life in the universe.

We achieve logical scientific progress in each element with a balanced program of flight projects complemented and supported by wide-ranging theoretical, laboratory, and ground-based observational programs and by suborbital observations. In response to, and in conjunction with, representatives of individual scientific disciplines, we define the purpose, number, timing, and chronological order of flight of projects considered necessary to meet the scientific objectives of the disciplines.

The programs identified in this plan for initiation within five years are those having the highest scientific priority. In phasing this integrated program, we explicitly considered issues such as discipline balance, maintenance of reasonable scientific momentum in the most critical areas of the program, generality of interest, status of each subdiscipline, and technological readiness. In addition, we shaped the program to try to take advantage of unique opportunities as they arise.

This space science plan is a deliberately ambitious one. The major scientific thrusts described are essentially the ones that would be pursued independent of whether they can all be initiated within the 1981-1985 period. Any major element that cannot be started as indicated will be initiated as soon as possible after 1985. Consequently, adjustments will affect the rate of progress but not the scientific content of the program.

#### B. Program Content

Completion of the total program contained in this 1981-1985 plan will provide significant advances in virtually all areas of space science. In particular, as we move from consideration of the universe as a whole, back through the solar system to the Sun and the Sun-Earth system, this plan provides for:

- o The first comprehensive survey of the infrared sky to be carried out by the Infrared Astronomy Satellite
- o Programs in ultraviolet and optical astronomy to be conducted with the Space Telescope, a facility of unparalleled sensitivity
- o Major steps forward in high-energy astrophysics to be provided for by development of the Gamma Ray Observatory and the Advanced X-Ray Astrophysics Facility
- o A basic new test of the theory of general relativity to be performed with Gravity Probe-B, and additional experiments in relativity to be carried out in the vicinity of the strong gravitational field of the Sun by the Solar Probe
- o Important astrophysics research to be continued with three new satellites in the Explorer program (Cosmic Background Explorer, Extreme Ultraviolet Explorer, and X-Ray Timing Explorer) and with Spacelab instruments, both the Principal Investigator class of instruments and multiuser instruments such as the Shuttle Infrared Telescope Facility
- o Exploration of the inner planets to be continued with the Venus Orbiting Imaging Radar

- o Information on the outer planets to be acquired from Voyager encounters with Saturn and Uranus and from the Galileo mission to orbit Jupiter
- o Reconnaissance of the small bodies of the solar system to be initiated with the Halley Flyby and Comet Rendezvous missions
- o The first exploration of the solar system in its third dimension -- away from the ecliptic plane -- by the International Solar Polar Mission
- o Continued vigorous progress in solar physics with studies of the Sun's active regions by the Solar Maximum Mission and observations of solar features at unprecedented angular resolution with the Solar Optical Telescope on Spacelab
- o Fundamental new observations of the Sun's internal mass distribution and corona and of the acceleration of the solar wind by the Solar Probe and Solar Corona Explorer
- o The first comprehensive systematic investigation of solar-terrestrial relations through study of the deposition, transport, and storage of energy in Earth's plasma environment by the Origins of Plasma in Earth's Neighborhood spacecraft; and additional experiments in basic space-plasma processes with Spacelab instruments and the Spacelab Chemical Release Facility
- o First steps in a dedicated life sciences Spacelab program to test hypotheses explaining medical and biological changes observed on previous space flights.

#### C. Schedule and Funding

Table 9 shows the phasing of the Space Science program and Figure 10 shows the program's funding requirements.

#### D. ASTROPHYSICS PROGRAM

The study of astrophysics involves scientific consideration of fundamental questions that have been at the core of human concern since the most primitive times. What are the size, scope, and structure of the universe? What is our place in it? How did it begin? Is it unchanging or does it evolve, and will it have an end? Do we completely understand the physical laws that govern it? Can we explain the enormous variety of observed celestial phenomena in terms of known physical laws, or will we have to revise those laws when we learn more about large-scale natural processes that cannot be duplicated in the laboratory?

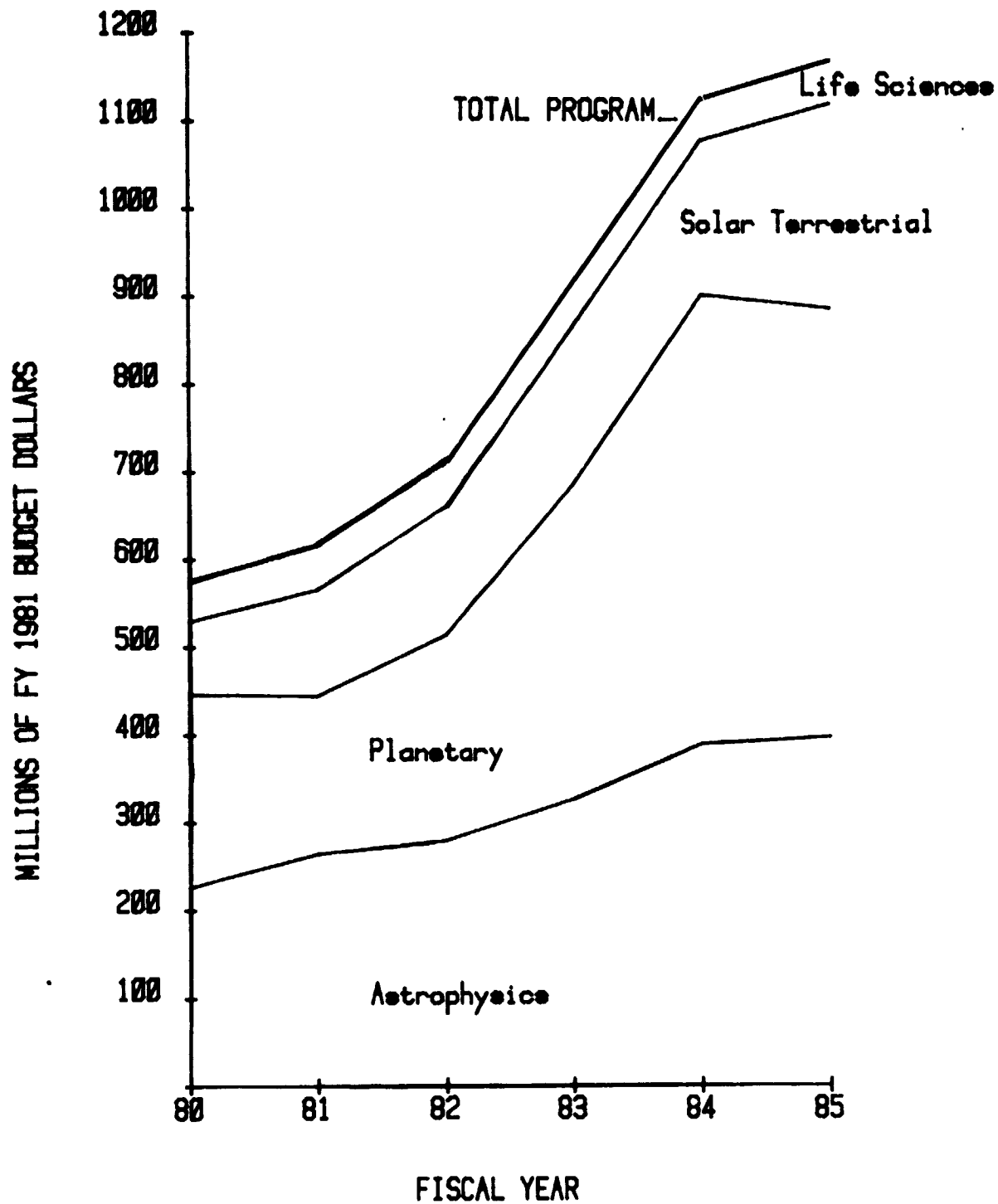
To obtain answers to those questions, we must study an incredibly diverse set of objects such as diffuse clouds of gas and dust, ordinary stars, pulsars, star clusters, galaxies, and quasars. The matter in those objects exists in a wide variety of forms and scales that range in density over at least 40 orders of magnitude and in temperature over millions of degrees. The radiation those objects emit ranges from highly energetic gamma rays and cosmic rays, through X-rays and the ultraviolet, to the lower energy "cool" infrared and microwave regions, and on into the radio region of the spectrum.

TABLE 9 -- SPACE SCIENCE PROGRAM SCHEDULE

PROGRAM	RESPON- SIBLE FIELD CENTERS *	PROGRAM PHASE		LAUNCH	ADDITIONAL IMPORTANT INFORMATION
		DEFINITION	INITIA- TION		
ASTROPHYSICS Infrared Astronomy Satellite Space Telescope Gamma Ray Observatory Cosmic Background Explorer Extreme Ultraviolet Explorer Shuttle Infrared Telescope Facility X-Ray Timing Explorer Advanced X-Ray Astrophysics Facility Gravity Probe-B	JPL, ARC MSFC, GSFC GSFC GSFC GSFC ARC GSFC MSFC MSFC	Completed	Ongoing	1982	Re-launch 1990
		Completed	Ongoing	1984	
		Ongoing	1981	1985	
		Ongoing	1981	1985	
		Ongoing	1982	1985	
		Ongoing	1982	1986	
		1980	1983	1986	
		Ongoing	1983	1987	
		Ongoing	1984	1988	
		Ongoing			
PLANETARY Galileo Halley Flyby Venus Orbiting Imaging Radar Comet Rendezvous	JPL, ARC JPL JPL JPL	Completed	Ongoing	1984	Halley encounter March 1986
		Ongoing	1982	1985	
		Ongoing	1982	1986	
SOLAR TERRESTRIAL Dynamics Explorer International Solar Polar Mission Active Magnetospheric Particle Tracer Explorer Chemical Release Facility Solar Optical Telescope Origins of Plasma in Earth's Neighborhood Solar Corona Explorer Solar Probe Plasma Turbulence Explorer	GSFC JPL GSFC MSFC GSFC GSFC GSFC JPL JPL	Completed	Ongoing	1981	Two spacecraft
		Completed	Ongoing	1983	
		Ongoing	1981	1983	
		Completed	Ongoing	1983	
		Completed	Ongoing	1985	
		Ongoing	1982	1985	
		1980	1983	1985	
		Ongoing	1985	1988	
		1980	1985	1987	
		Ongoing			
SPACELAB PAYLOADS OSS-1 Pallet Spacelab 1 Spacelab 2 Life Sciences Follow-on Missions	GSFC MSFC MSFC JSC	Completed	1978	1982	Launch of three spacecraft 1985, fourth 1986
		Completed	1978	1982	
		Completed	1979	1983	
		Ongoing	1979	1984	
Physics and Astronomy Follow-on Missions	GSFC, MSFC	Ongoing	1979	1984	Continuous at rate of one mission every 18 months Continuous at rate of 2-1/2 missions per year

\* ARC = Ames Research Center      JPL = Jet Propulsion Laboratory      MSFC = Marshall Space Flight Center  
 GSFC = Goddard Space Flight Center      JSC = Johnson Space Center

FIGURE 10.  
SPACE SCIENCE PROGRAM FUNDING



For centuries, our limited abilities kept us from obtaining a complete picture of the universe, and we could make little real progress in understanding the universe without that complete picture. Until the space age, we could observe the heavens only through "the dirty basement windows of the atmosphere." Water vapor in the atmosphere blocks much of the infrared spectrum; and celestial radiation in the ultraviolet, X-ray, and gamma-ray frequencies does not penetrate the atmosphere at all. Even at the wavelengths of visible light, atmospheric scintillation limits the performance of the most advanced ground-based telescopes.

As a result of this country's program in space astronomy and astrophysics, a new view of the universe has emerged during the past two decades. Rocket and satellite observations at ultraviolet wavelengths have shown that many types of stars are ejecting significant amounts of material at high velocities. A revolution has occurred in our knowledge of the chemical composition and physical state of the interstellar gas and dust. We now know from both ultraviolet and X-ray observations that many types of stars possess high-temperature, tenuous outer layers and exhibit solar-like activity, but display detailed behavior very different from that expected on the basis of our current understanding of the solar chromosphere and corona. Discovery of celestial X-ray and gamma-ray sources has revealed the existence of entirely new types of celestial objects and has shown that humanity lives in a universe characterized by the routine occurrence of vast explosive events of unimaginable violence. Evidence accumulated from X-ray measurements suggests that a significant fraction of the matter in the universe may exist in the form of very high temperature gas located between the galaxies. We have observed X-rays emitted from objects ranging from nearby cool stars to the most distant quasars, and recent observations have shown that some of the most interesting types of astronomical bodies are emitting the bulk of their energy in the form of gamma rays. These new discoveries have been made at an astonishingly rapid pace. Our future Astrophysics program is designed to continue this revolution in our understanding of the universe.

#### 1. Program Goal

The goal of the Astrophysics program is to understand the origin and evolution of the universe and the fundamental laws of physics that govern cosmic phenomena.

#### 2. Program Strategy

##### a. Investigation Stages

Five distinct stages can be identified in the strategy used in the Astrophysics program:

- o Preliminary surveys to see if anything is there and to detect gross features
- o Initial all-sky surveys to acquire initial statistical information on source characteristics, determine approximate source locations, and collect other useful data
- o Detailed studies of individual sources or high-sensitivity surveys
- o Flight of full-scale observatories
- o Flight of specialized follow-on and observatory-support missions.

In addition, we may develop individual missions to study specialized or unique problems requiring use of the space environment.

We make typical "first cuts" using ground-based telescopes, aircraft such as the C-141 Kuiper Observatory, sounding rockets, and balloons. In the future, we will also use Spacelab.

We may also use those vehicles to develop and test new types of instruments before using the instruments on major free-flying satellites. Examples of initial survey missions include those by the UHURU X-ray satellite and the Infrared Astronomy Satellite (IRAS), which is currently under development. The first survey of the sky for gamma-ray line emissions is now being carried out by one of the instruments on the third High Energy Astronomy Observatory, HEAO-3. HEAO-2, which is the first true imaging astronomical X-ray telescope, is bringing X-ray astronomy into the detailed study stage. And the Space Telescope, building on a long history of ground-based astronomy and on a series of ultraviolet space astronomy missions, will move ultraviolet and space optical astronomy into the mature observatory stage.

#### b. Status of Astrophysics Disciplines

Different disciplines within astrophysics are at very different stages of development. At the bottom of the ladder of five stages, we have only recently detected the first extreme ultraviolet sources. The next step will be to carry out the initial all-sky survey. At the other extreme, ultraviolet and optical astronomy will, as stated above, be advanced into the mature observatory stage by the Space Telescope.

In general, different wavelengths (or particle-energy ranges) provide information on different physical objects and on different physical processes in a given object. To obtain a complete picture of what is going on in our universe, we must advance all the astrophysics disciplines.

### 3. Program Content

#### a. Current Program

##### (1) Space Telescope

The principal element in the current Astrophysics program is the 2.4-meter diameter Space Telescope, now in development. Its ability to cover a wide range of wavelengths, to provide fine angular resolution, and to detect faint sources will make it the most powerful astronomical telescope ever built. We will use it to attack a wide variety of frontier problems in astrophysics, particularly in the areas of extragalactic astronomy and observational cosmology. The Space Telescope will be a long-lived orbital facility launched and serviced by the Space Shuttle, which will be used to change and update the Space Telescope's focal plane instruments as scientific priorities and instrument capabilities evolve.

## **(2) Infrared Astronomy Satellite**

In infrared, IRAS will carry out the first comprehensive all-sky survey in the 8- to 120-micron region of the spectrum. That survey is expected to detect as many as 10 million infrared sources and obtain sufficient crude spectral information to identify the most interesting of those sources for intensive study with later instruments. The survey will be complemented by an extended source survey to be carried out with a small telescope on Spacelab 2.

## **(3) High-Energy Astrophysics**

The final launch in our current program of major missions in high-energy astrophysics was of HEAO-3 on September 20, 1979. NASA's accomplishments have earned the United States preeminence in this important field. Opportunities for additional research between 1982, when HEAO-2 is expected to cease operations, and the next generation of free flyers described under New Initiatives below will be provided primarily by sounding rockets, balloons, and a relatively limited number of Spacelab flights.

For cosmic ray and X-ray astronomy, we have selected investigator-supplied Spacelab instruments for study and development in a series of Spacelab flights between 1982 and 1985. An example is an instrument being developed for Spacelab 2 that will study the chemical composition and energy spectra of very high energy cosmic rays. Instruments of this type developed initially for use on the Shuttle may later be used on free-flying satellites or space platforms to obtain definitive measurements of cosmic ray particles that have the very highest energies and charges and that are, therefore, of primary scientific interest.

We have also selected Spacelab instruments for further study and development in ultraviolet, infrared, and radio astronomy. We will use those instruments to study specific limited scientific problems, to test new concepts for instruments, and to explore possible new areas of space astronomy.

### **b. Technological Progression**

The current program and the new initiatives in this Astrophysics program plan reflect an integrated, evolutionary approach to achieving the program's goal. New missions build on the scientific accomplishments and technological developments of earlier programs. For example, updated experiments, related hardware, and experience from previous sounding rocket, balloon, Explorer, Orbiting Astronomy Observatory, and HEAO activities will be used in the Space Telescope, Spacelab, and high-energy follow-on missions, as appropriate. Both the hardware and the scientific experience from IRAS will contribute directly to the Shuttle Infrared Telescope Facility. New generations of large instruments for high-energy astrophysics investigations will be tested and used initially on Spacelab, and then on free-flyers and space platforms.

We will use space in developing progressively greater experimental and observing capabilities. Most important of all, to plan properly for the future, we must continuously think in terms of a comprehensive long-term program. For that reason, the description of our planned Astrophysics program that follows includes not only the programs that we want to initiate

during the 5-year planning period, but also programs to be initiated later in the coming decade. That longer-term view is essential to the shaping of an integrated, comprehensive program and to ensure that the technological base for such a program is well established.

### c. Major New Initiatives

#### (1) Gamma Ray Observatory (GRO)

GRO will move gamma-ray astronomy from the initial survey stage to the detailed study stage. Gamma-ray measurements reveal the explosive, high-energy, nuclear and elementary particle processes that occur in the universe. High-sensitivity observations of gamma-ray line emissions in supernovae and their remnants can provide direct evidence of nuclear reactions that we believe lead to synthesis of elements. Gamma rays produced by interactions of cosmic rays with the interstellar medium provide direct information on both the interstellar gas and the cosmic rays. Observations of gamma rays from objects such as pulsars, which also emit radiation in the radio, visible, and X-ray regions, are essential to detailed understanding of the objects. Because of their extreme penetrating power, gamma rays retain the detailed directional and temporal features imprinted on them at their birth, even if that birth was deep in regions opaque to visible light and X-rays, or was early in the history of the universe.

#### (2) Advanced X-ray Astrophysics Facility (AXAF)

A direct descendant of HEAO-2, AXAF will take X-ray astronomy into the mature observatory stage. The focal plane of AXAF's 1.2-meter grazing incidence X-ray telescope will be able to accommodate a variety of instruments to provide spectral and high-spatial-resolution data on quasars, galaxies, clusters of galaxies, and the intergalactic medium. AXAF will be launched, serviced, and retrieved by the Space Shuttle. With four times the spatial resolution and at least twenty times the sensitivity of HEAO-2, AXAF will be as large an advance in X-ray astronomy as the Space Telescope is in optical astronomy.

#### (3) Gravity Probe-B (GP-B)

The orbiting-gyroscope experiment, GP-B, will carry out a fundamental test of the theory of general relativity by measuring the precession of an orbiting gyroscope produced by its movement through a gravitational field (relativistic spin-orbit coupling) and by the twisting of space caused by the rotation of the Earth (relativistic spin-spin coupling). High-precision measurement of the magnitude of those two effects will be a fundamental step in evaluating competing theories of gravitation, and the necessary precision can be achieved only in the space environment.

### d. Other New Initiatives

#### (1) Cosmic Background Explorer (COBE)

COBE will measure with high precision the spectrum and directional distribution of cosmic microwave background radiation. That radiation is believed to be a remnant of the "big bang" explosion that produced the present universe. Measurements made from Earth, balloons, and aircraft are subject to relatively large uncertainties. This satellite experiment will provide the definitive information that measurements from Earth cannot provide on a fundamental observation in cosmology.

(2) Extreme Ultraviolet Explorer (EUVE)

This Explorer satellite will carry out the initial survey of the sky for objects emitting primarily in the 100-900Å region of the spectrum, thereby opening up one of the last remaining unexplored spectral regions. EUV objects discovered to date have all been stars at very advanced stages of their evolution. We believe that discovery of a large number of those objects will lead to new insight on the late stages of stellar evolution, as well as on the energetics of the interstellar medium.

(3) X-Ray Timing Explorer (XTE)

XTE will be an X-ray mission devoted to intensive studies of the time variability of X-ray sources over a range from milliseconds to years. X-ray sources vary and a key property is the temporal pattern of their variations. The details of the time behavior carry important information on the underlying physical processes taking place in objects such as magnetic white-dwarf stars, X-ray binaries, neutron stars, and pulsars. Observations with modest instruments sensitive to a wide range of X-ray energies (2 to 30 keV) are required over extended periods for study of known sources and for detecting transient events.

(4) Astrophysics Explorer Continuing Program

We will define and study additional astrophysics Explorers during the next two years. We have already identified a number of candidate missions, including a far ultraviolet (900-1100Å) high-resolution spectroscopy mission, an X-ray spectroscopy mission, a soft X-ray mission, and an ultra-heavy cosmic ray mission. We plan to add Explorers to the Astrophysics program starting in 1984 at the rate of at least one Explorer every other year.

(5) Shuttle Infrared Telescope Facility (SIRTF)

SIRTF will be a meter-class, cryogenically cooled, infrared telescope designed to study the very cold regions of space where cosmic dust and gas are condensing into stars, cool solar-system objects (such as asteroids), and infrared-emitting extragalactic objects. Because SIRTF will operate above Earth's obscuring and emitting atmosphere and will use cooled optics, it will provide a more than thousand-fold increase in sensitivity at wavelengths observable from the ground, and even a hundred-fold increase over the sensitivity of a space-based warm-optical system like that in the Space Telescope. One major application of SIRTF will be to carry out detailed infrared spectroscopy and spectrometry of the faint infrared sources that IRAS is expected to discover. Detailed observations of those sources will not be possible with any other planned telescope.

(6) Spacelab Proof of LAMAR Concept

In high energy astrophysics, specialized instruments that will ultimately be used on free flyers and space platforms will sometimes be developed for initial use on Shuttle-Spacelab flights. Those flights are well suited for tests of instruments and for conducting investigations of limited, specific problems, but will not provide the long integration times generally required for observations in this field. In particular, we will

develop an early version of the Large Area Modular Array (LAMAR) X-ray telescope, which is described later, for use on Spacelab to test the LAMAR concept and to study selected problems requiring LAMAR's planned capability. Development of competing LAMAR concepts for flight test is now in process as part of the Spacelab program.

(7) Starlab

We will use this Shuttle-based, meter-class, ultraviolet and optical instrument to carry out, with high angular resolution, imaging investigations of sources that are too large to be observed efficiently with the Space Telescope. Those sources include globular clusters, gas clouds, nearby galaxies, and large clusters of galaxies. We will also use Starlab as a test bed for advanced instruments to be used ultimately on the Space Telescope.

e. Other Scientifically Desirable Program: Cosmic Ray Observatory (CRO)

There is an additional major program we would have included as a new initiative in this 5-year plan if resources had permitted. If funding becomes available, it will be added; or, if an initiative that is now in the plan is delayed for some reason, it will be substituted for that delayed initiative. Otherwise, it will be a post-1985 initiative. It is the Cosmic Ray Observatory, which is scientifically important, technically ready, and could be initiated any time in the 1981 through 1985 period.

CRO will use large, massive, instruments — initially tested and used on Spacelab flights — to carry out measurements in cosmic ray physics requiring long observing times and, therefore, free-flying spacecraft or space platforms. We will emphasize measurements of particles of very high energy and low flux. We will make frontier investigations of the charge composition, energy spectra, arrival direction, and isotopic composition of cosmic ray nuclei. We also will search for exotic particles such as super-heavy nuclei, magnetic monopoles, and anti-nuclei.

f. Programs for Initiation After 1985

In structuring the Astrophysics program to meet its goals and to follow the strategy established for it, we have identified and are continuing to identify additional requirements and missions for a comprehensive program throughout the 1980s and into the 1990s.

(1) X-Ray Astronomy

In X-ray astronomy, we have already identified a need for two observatory-supported missions that will complement AXAF's capabilities.

(a) X-Ray Observatory (XRO)

XRO will use a complement of X-ray instruments to make special measurements that do not require focusing optics and that systems like AXAF cannot accommodate. Such instruments include iron-line spectrometers, X-ray polarimeters, and instruments for studying energy ranges that AXAF cannot study.

(b) Large Area Modular Array (LAMAR) X-Ray Telescope

LAMAR will be an X-ray telescope capable of conducting a deep-space survey to establish the distribution of extragalactic X-ray objects. LAMAR

will consist of many small modules, each with its own detector, assembled to form a collector with a very large area. Both HEAO-2 and AXAF have sensitivities limited by their collecting areas -- about 150 and 600 cm<sup>2</sup>, respectively. In contrast, LAMAR's collecting area can be built up to as much as 10,000 cm<sup>2</sup> to achieve great sensitivity. That sensitivity will be gained at the expense of angular resolution, which will be about 1 arc minute. Thus, LAMAR will be able to perform studies that do not require precise angular resolution but do require great sensitivity, either because the sources are intrinsically faint or because they vary rapidly in intensity.

## (2) New Observing Capabilities

We are also considering ways to develop other new capabilities for making observations from space and to dramatically extend existing capabilities. Two specific areas that are of very high interest are development of large flux collectors for measurements in the ultraviolet, optical, infrared, and millimeter-wave portions of the spectrum, and development of space-based interferometers to perform a variety of new and novel measurements.

### (a) Large Flux Collectors

By the 1990s, our ability to study many frontier astronomical problems will be limited by the weakness of the radiation received from sources that are intrinsically faint and extremely distant. Study of those sources will require development of a generation of telescopes having very large collecting areas and large-aperture, high-precision optics that can achieve significant increases in angular resolution, particularly at infrared and millimeter wavelengths. Possibilities for such large flux collectors include a Large (10- to 30-meter diameter) Ambient Deployable Infrared Telescope, an Orbiting Submillimeter Telescope, and a very large (10-meter equivalent aperture) diffraction-limited optical telescope.

### (b) Interferometers

Three space interferometry activities have potential for development. The first, very long base line radio interferometry, will use an orbiting radio antenna 10 to 30 meters in diameter in conjunction with existing ground-based radio-astronomy facilities to produce radio "pictures" of unprecedented angular resolution ( $10^{-3}$  to  $10^{-5}$  arc second). We need maps with that degree of detail for study of the physics of quasars and galactic cores, of interstellar masers, and of the dynamics of star formation. Use of an antenna in Earth orbit will remove ambiguities that seriously affect interpretation of radio maps, and will permit use of significantly longer base lines (leading to higher angular resolution) than can be used on Earth. We are studying a preliminary test of this concept to be carried out with a radio antenna mounted on Spacelab.

The second interferometry activity relates to detection of gravitational waves and will require a very large interferometer in space. The history of science provides countless illustrations of the fact that development of a major new technical capability permits exploration of entirely new scientific "territory." In this case, the Shuttle is expected to provide the needed capability for fabricating in space the very large interferometer required for detection of gravitational waves. Relativistic theories of gravitation predict that gravitational radiation is generated by any non-spherical, dynamically changing system of masses. Possible sources of

gravitational waves include pulsars, short-period binary stars containing compact objects, and massive rotating stars that are collapsing to form black holes. The possibility of detecting gravity waves raises the fascinating prospect of an era of observational gravitational astronomy.

The third interferometry activity will also require very large structures. It is space-based interferometry at ultraviolet, optical, and infrared wavelengths to study features very small in scale, and possibly to resolve the disks of stars and detect planets. Conceivable base lines for the interferometers range from tens of meters to a kilometer or more.

#### (c) Additional Tests of General Relativity

Tests of general relativity in addition to the one to be performed by Gravity Probe-B are possible using missions in other program elements of the Space Science program. For example, solar missions and planetary missions into deep space can be tracked accurately to detect very small changes in their trajectories that gravitational waves might produce. Also, a mission such as the Solar Probe may provide a valuable opportunity for studying relativistic effects in the high gravitational field near the Sun.

#### g. Technology Requirements

The success of the Astrophysics program depends partly on progress in several areas of technology. Continuing development of high-sensitivity detectors at all wavelengths is urgently needed. Studies must be made of problems associated with adapting and using on free-flyers and space platforms experiments originally developed for Spacelab. Very long base line interferometry and astronomy at millimeter and submillimeter wavelengths will require careful development of technology for deployment, construction, and use of large antennas in space, as well as for new types of sensitive radio receivers. Assembly or fabrication in space of large structures may also be needed for the next generation of very large instruments for high-energy astrophysics experimentation, as well as for the large flux collectors and interferometers mentioned above. Development may be required of techniques for maintaining, with high precision, the base lines and alignment of large structures and for highly accurate pointing of such structures.

Development of large flux collectors will require advances in optics technology, particularly in the figuring and control of large surfaces. We also need to investigate new approaches to optical design, such as the use of segmented mirrors and new techniques for machining X-ray mirrors. The ability to fly dual-frequency transponders routinely on planetary and solar missions is needed for tests of the theory of relativity involving solar system dynamics. Use of deep space probes for meaningful searches for gravitational waves may require substantial improvements in the technology of drag-free control and in spacecraft tracking and communications. There may also be a need for development of long-life, ultra-stable clocks.

The Office of Space Science (OSS) will develop some of those needed technologies, especially those related directly to OSS flight programs. The other program offices will develop other needed technology. For example, the Office of Aeronautics and Space Technology is developing technology for materials and structural designs for large space structures, as well as technology for maintaining the structures' geometry, position, and

orientation in space. The Office of Space Transportation Systems is developing technology for deploying, fabricating, and servicing those structures in space.

#### 4. Schedule and Funding

The phasing of the initiatives in the Astrophysics program is contained in the schedule for the complete Space Science Program in Table 9. Figure 11 shows the Astrophysics program's funding requirements, and Figure 12 illustrates how each of the program's initiatives contributes to achievement of the overall strategy.

#### E. Planetary Program

The United States program for solar system exploration has benefited the Nation greatly in terms of new knowledge, national prestige, and pride. Our spacecraft were the first to visit Mercury, Venus, and Mars. We have landed two highly advanced spacecraft on Mars to search for life on that planet, and our spacecraft were the first to cross the asteroid belt and encounter the giant planet, Jupiter. Our Voyager spacecraft, after historic observations of Jupiter and the four Galilean satellites, are currently committed to fly to Saturn and possibly to Uranus. The Apollo astronauts returned hundreds of kilograms of samples from six locations on the Moon.

The scientific yield from those missions has been enormous. We are beginning to understand how atmospheres evolve; and, by virtue of studying the dynamics, chemistry, and evolution of the atmospheres of our sister planets, Venus and Mars, we may get an insight into what the future has in store for our planet, Earth. We are beginning to understand the origins of Earth and the solar system. Our program will ultimately result in an understanding of the conditions that caused life to develop on Earth and not on any other planet in our solar system. This already large body of knowledge is the profound legacy we have accumulated and will leave to succeeding generations.

##### 1. Program Goal

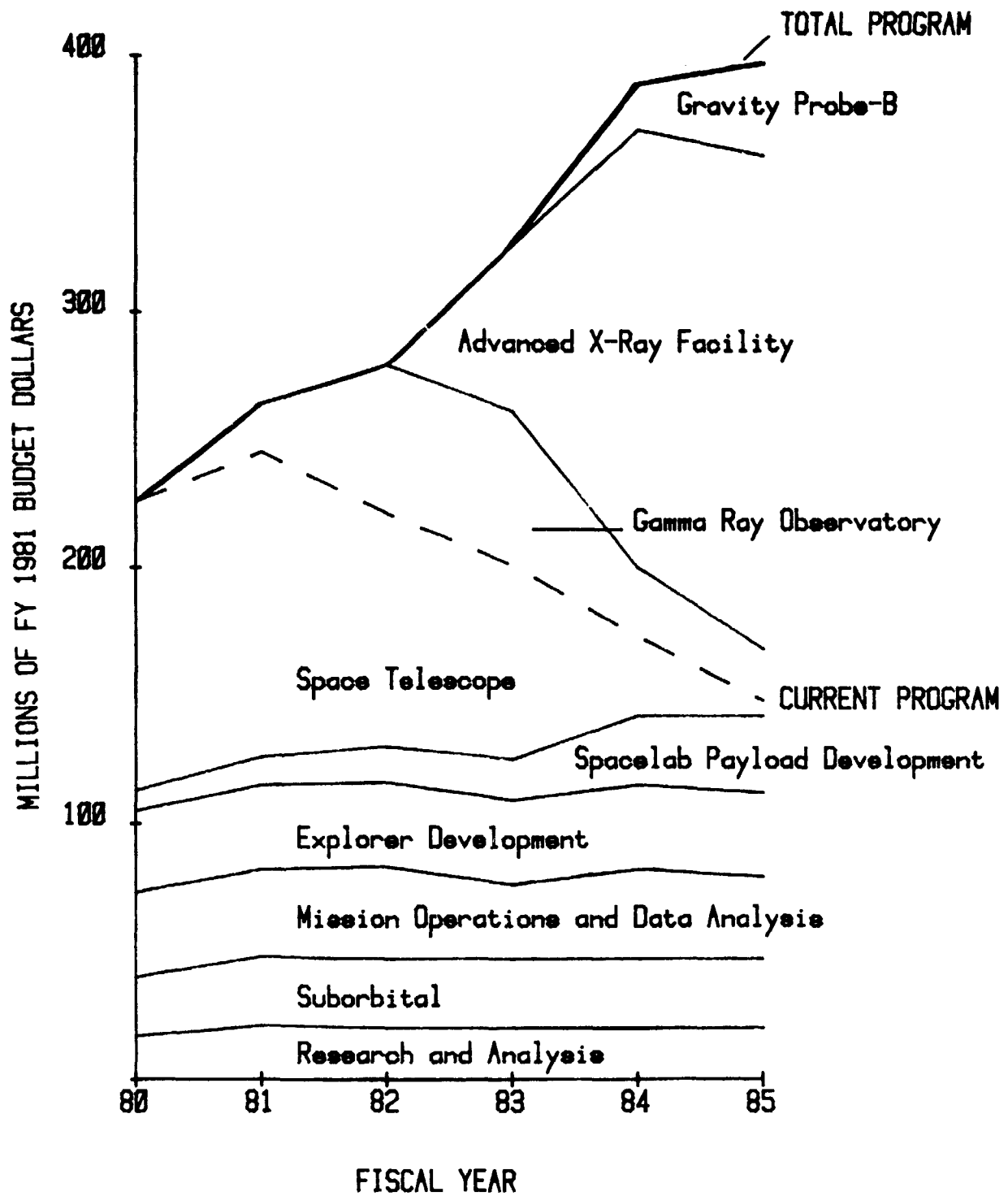
The goal of the Planetary program is to understand the physics, chemistry, and evolution of all the bodies in the solar system and their relationship to the interstellar medium.

##### 2. Program Strategy

The strategy the program follows for studying each body in order to achieve that goal is to:

- o Obtain an initial reconnaissance of the body
- o Initiate exploration of the body with a focus defined from the initial reconnaissance phase
- o Conduct an intensive study of the body covering very specific and crucial scientific issues identified during the exploratory phase.

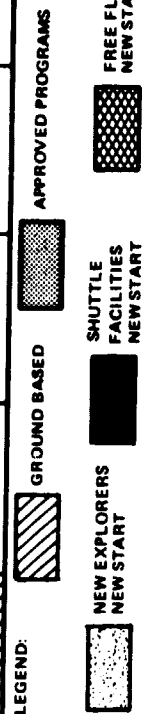
FIGURE 11.  
ASTROPHYSICS PROGRAM FUNDING



# FIGURE 12 — THRUSTS IN ASTROPHYSICS

DATA BASE	TYPICAL PROBLEMS	FIRST CUT	INITIAL SURVEY	DETAILED STUDY	MATURE OBSERVATORY	OBSERVATORY SUPPORT	SPECIALIZED TECHNIQUES
COSMIC RAYS	FORMATION OF ELEMENTS	Balloons	SPACELAB HEAD-3	COSMIC RAY OBSERVATORY			
GAMMA RAYS	PULSARS INTERSTELLAR GAS (LOCATION)	Balloons	SMALL ASTRONOMY SATELLITE-B HEAD-3	GAMMA RAY OBSERVATORY			
X-RAYS	INTERGALACTIC MATTER	Rockets	SHUTTLE HEAD-1	HEAD-2	AAAF	LAMAR	X RAY TUNING EXPLORER
SOFT X-RAYS	INTERSTELLAR GAS (COMPOSITION)	Rockets	HEAD-1				
EXTREME ULTRAVIOLET	DYING STARS	APOLLO-SOYUZ TEST PROJECT	EUV EXPLORER				
ULTRAVIOLET	HOT STARS	Rockets	ORBITING ASTRONOMY OBSERVATORY-2 (OAO-2)	OAO-3 INTERNATIONAL ULTRAVIOLET EXPLORER		STARLAB	
VISIBLE	QUASARS, NORMAL STARS				SPACE TELESCOPE		
INFRARED (WARM OPTICS)	IONIZED GAS, GALACTIC CENTER						
INFRARED (COLD OPTICS)	INTERSTELLAR DUST	Balloons Rockets	AIRBORNE SPACELAB IRAS	LARGE MIRROR TELESCOPE SYSTEM			
MICROWAVES	BIG BANG	AIRBORNE Balloons	COBE	SRTF			
RADIO	EXPLODING GALAXIES, INTERSTELLAR ELECTRONS						
RELATIVITY	NATURE OF GRAVITY						GRAVITY PROBE-B COSMIC PROBES

LEGEND:



NASA HQ SA 78-1219 (3)  
REV. 7-25-90

### **3. Status of Solar System Exploration**

#### **a. Reconnaissance**

Reconnaissance missions are generally accomplished by flyby spacecraft. We have completed reconnaissance of the solar system's inner planets and have initiated reconnaissance of three -- Jupiter, Saturn, and Uranus-- of the outer planets with Pioneers 10 and 11 and Voyagers 1 and 2. However, our study of primitive bodies -- comets and asteroids -- in the solar system has been restricted to Earth-based observations. Those bodies are unique in spatial and size distribution. They range from very small bodies to bodies nearly 1,000 kilometers in diameter, and they travel in orbits reaching from the stellar interface to catastrophically close to the Sun. Because we expect them to play a key role in our theories about our solar system's evolution, we plan to initiate, in the 1981 through 1985 period, two missions for reconnaissance of them, a flyby of Halley's comet and a detailed reconnaissance of a short-period comet. Comet Tempel 2 is the reference target for this report, but studies currently in process will select the optimum target.

Reconnaissance missions to study specific primitive bodies will require propulsion beyond that which the Shuttle and Inertial Upper Stage can provide. The Solar Electric Propulsion System will supply the low-thrust, high-impulse propulsion required. It will be a system whose propulsive medium will be ions energized by electricity from solar power. It will be developed by NASA's Office of Space Transportation Systems for use in the Comet Rendezvous mission, as well as in many other planetary missions starting after 1981.

#### **b. Exploration**

Exploration missions are best accomplished with orbiting spacecraft in combination with entry bodies and landers, the former to determine geological, geophysical, and geochemical properties on a global scale, and the latter to make in situ measurements of atmospheric or surface characteristics, or both.

Venus is the terrestrial planet most like Earth in size and location, but is the least explored and least understood of the terrestrial planets. High-resolution maps of its surface topography are vital to our comparative planetology activities. However, because clouds shroud Venus continuously, we can obtain the maps only with radar. To answer such questions as whether Earth might evolve into a Venus-like planet, we must supplement the information derived from our earlier Mariner and Pioneer reconnaissance and initial exploratory missions. Consequently, we have included in this Planetary program a mission, Venus Orbiting Imaging Radar, to map the surface of Venus with an imaging radar on an orbiting spacecraft.

Jupiter and Saturn, the two giant planets of the solar system, each has ten or more satellites (moons). Three of the moons are about the size of Mercury, with the largest of the three, Saturn's moon Titan, larger than Mercury. We began reconnoitering Jupiter and Saturn with our Pioneer and Voyager missions. We will obtain more detailed reconnaissance and initial exploration of the Jupiter system with the Galileo mission, which will

include an orbiter and an atmospheric probe. The Space Science Board of the National Academy of Sciences has concluded that initiation of exploration of the Saturnian system in the middle 1980s is essential to the Nation's broad plan of space exploration. However, because of budget restraints, we could not include in this 5-year plan an initiative for exploration of the Saturnian system.

#### c. Intensive Study

We have completed initial exploration of the Moon and Mars. The yield from the enormously successful Viking mission would enable us to initiate, immediately, a program to conduct intensive study of Mars, the most Earth-like planet in the solar system. However, budget restraints prevent us from including a Mars initiative in this 5-year plan.

#### 4. Planning Assumptions

Our ability to conduct the Planetary program on the schedule planned for it is based on the assumption that the Solar Electric Propulsion System (SEPS) will be ready for launch in July 1986.

#### 5. New Initiatives

##### a. Venus Orbiting Imaging Radar (VOIR)

VOIR will map the entire globe of Venus with a resolution better than one kilometer, and with a best spot resolution of 100 meters. The equivalent mission at Mars, Mariner 9, detected the existence of volcanoes, huge canyons, and river beds, completely altering our understanding of the geological evolution of Mars. We expect VOIR's contribution to our knowledge of Venus to be as significant as Mariner's was for Mars.

##### b. Comet Reconnaissance Program

This program will yield the first reconnaissance data on the small bodies of the solar system and the first look at the nucleus of a comet. It will detect parent molecules in the inner coma, explore cometary atmospheric dynamics, and measure chemical constituents of the nucleus and dust. In keeping with our general comparative strategy, we have selected two comets for reconnaissance: Halley, a young, bright comet, and a relatively old and less bright comet -- tentatively, Tempel 2. (Other short-period comets suitable for a rendezvous mission include Encke and Faye.) Our earlier plans called for a combined mission to both targets. However, delay in initiation of SEPS, which is required for a rendezvous mission, has forced us to plan two separate missions.

##### (1) Halley Ballistic Flyby

This mission will capitalize on the unique opportunity that Halley's only apparition this century will provide. It will view Halley, a relatively young comet, close up and will complement investigations planned by other nations. However, because it will fly by Halley at high velocity, it will not be able to investigate Halley's nucleus in detail.

##### (2) Comet Rendezvous

This mission will investigate the nucleus of a comet before, during, and after the comet's passage through perihelion by rendezvousing with and

maneuvering in the vicinity of a short-period older comet. It will examine the comet in detail over a period of approximately one year.

#### 6. Programs for Initiation After 1985

Intensive study of Mars, exploration of Saturn, and reconnaissance of asteroids are important future initiatives. Consequently, the following endeavors are our highest priority objectives after 1985.

##### a. Mars Sample Return Mission

The purpose of this mission will be to return soil and rock samples from several distributed locations on Mars selected for their aggregate scientific value. We expect that analysis of those samples in Earth-based laboratories will enable us to determine the age and chemical evolution of Mars, just as our lunar samples have enabled us to understand the Moon's history. Part of our analysis will try to determine whether life could have existed on Mars in an earlier age.

The Mars program will also determine some of the fundamental processes governing that planet's formation. It ultimately will consist of three elements -- global geochemical mapping of elemental abundances by an orbiter, determination of geological diversity by a rover, and analysis of samples returned to Earth. All three of those elements are considered essential. Return of samples to Earth for analysis is particularly important because testing in Earth-based laboratories can be much more comprehensive and adaptable than remote testing can be. Integration of data from all sources -- geochemical mapper, completed Viking missions, rover, and returned samples -- will guide further development of theories about the formation and nature of Mars.

##### b. Saturn Orbiter Dual Probe Mission

The logical mission to follow Galileo in exploration of the outer solar system is the Saturn Orbiter Dual Probe mission. The systems constituting that mission are a Saturn probe, a Titan probe, and a Saturn orbiter. Together, those three systems will yield in situ measurements of Saturn's atmosphere, Titan's atmosphere, and possibly Titan's surface; remote observations of Saturn, its rings, and some others of its satellites; and detailed mapping of Saturn's magnetosphere.

Special investigation of Titan is important because Titan is unique in size and appearance. Its unique appearance indicates the presence of an extensive atmosphere and, possibly, of organic materials. This planned Saturn mission will use the same hardware technology that the Galileo mission to Jupiter is using, and it will provide important data for comprehensive planetology studies of those two complex planetary systems. It will require use of the Solar Electric Propulsion System to be developed for the earlier Comet Rendezvous mission.

##### c. Asteroid Multiple Rendezvous

This mission will enable us to understand the nature of the differences among the major classes of asteroids in the main belt. It will consist of sequential rendezvous with one of the major asteroids (Ceres or Vesta), an asteroid we presume is siliceous, one we presume is carbonaceous, and one we presume is metallic.

#### d. Other Possible Long-Range Programs

During the early 1990s, a favorable conjunction of the planets will give us an opportunity for initial reconnaissance of the far outer planets, Neptune and Pluto. Also, we hope to conduct a sample return mission to a comet and one to a near-Earth asteroid. Other possibilities for programs to be started after 1985 are: first, exploration of Mercury with a low-altitude orbiter occupying a circular polar orbit, and possibly augmented with a simple lander; and, second, use of the global data from the VOIR mission to determine optimum locales on Venus for in situ surface analysis.

#### 7. Schedule and Funding

The phasing of the initiatives in the Planetary program is contained in the schedule for the complete Space Science program in Table 9. Figure 13 shows the Planetary program's funding requirements, and Figure 14 depicts the progress toward a truly comprehensive understanding of the solar system that will result from the Planetary program proposed in this plan.

#### F. Solar Terrestrial Program

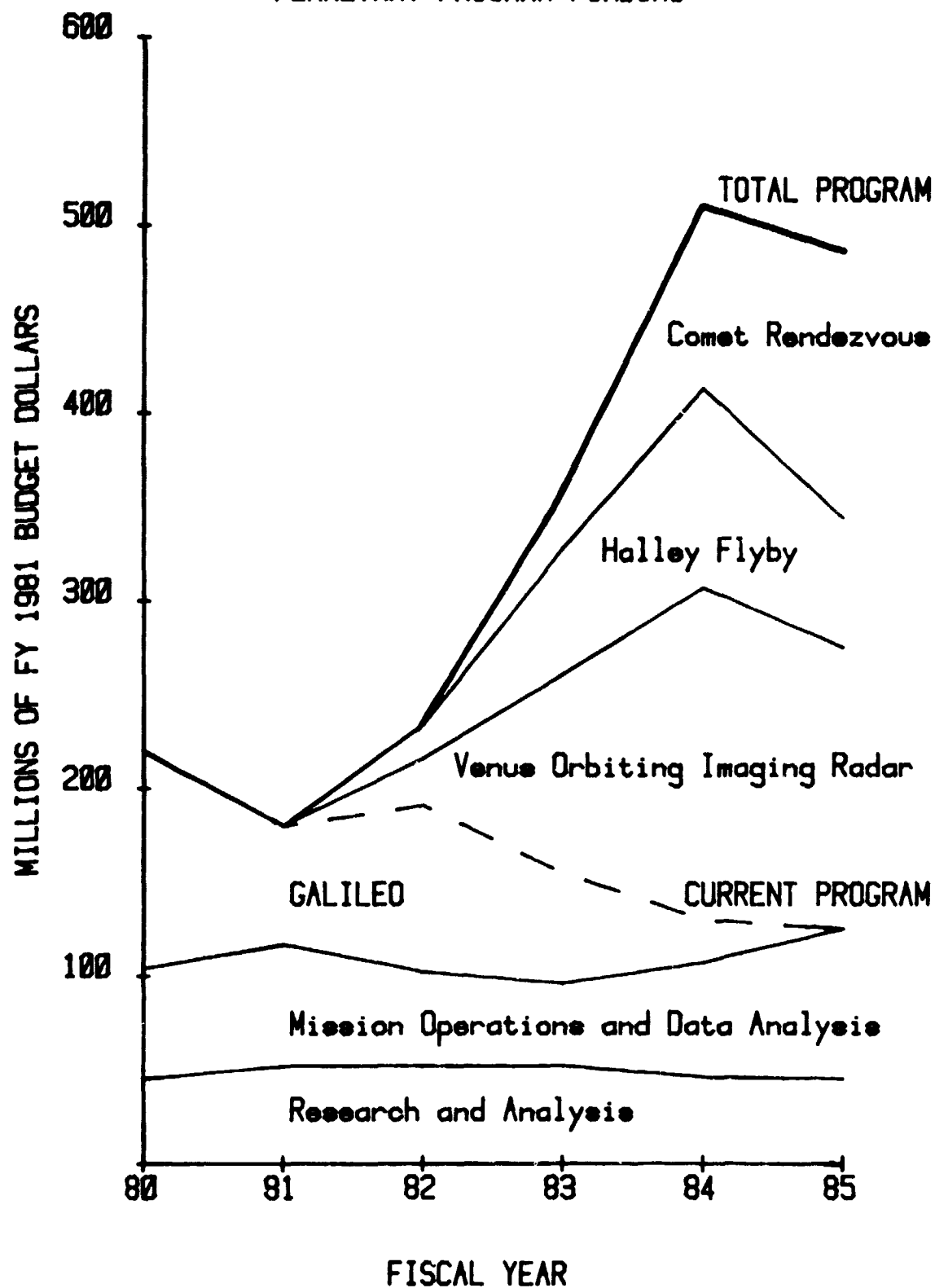
We may have reached the point in our evolution where our environment and our intellect determine our future. If so, important results we obtain by exercising our intelligence will depend on our perception and understanding of our natural environment and our influence upon it. It is therefore fundamental to our intellectual and physical well-being that we understand the Sun, the terrestrial environment, and the relationships and coupling between them. Knowledge of solar-terrestrial relations is important because those relations embody many of the vital physical aspects of our environment and have intellectual and physical significance beyond their subject matter.

NASA's space program has achieved significant progress in identifying the structure of the Sun, the heliosphere, and Earth's magnetosphere, ionosphere, and upper atmosphere.

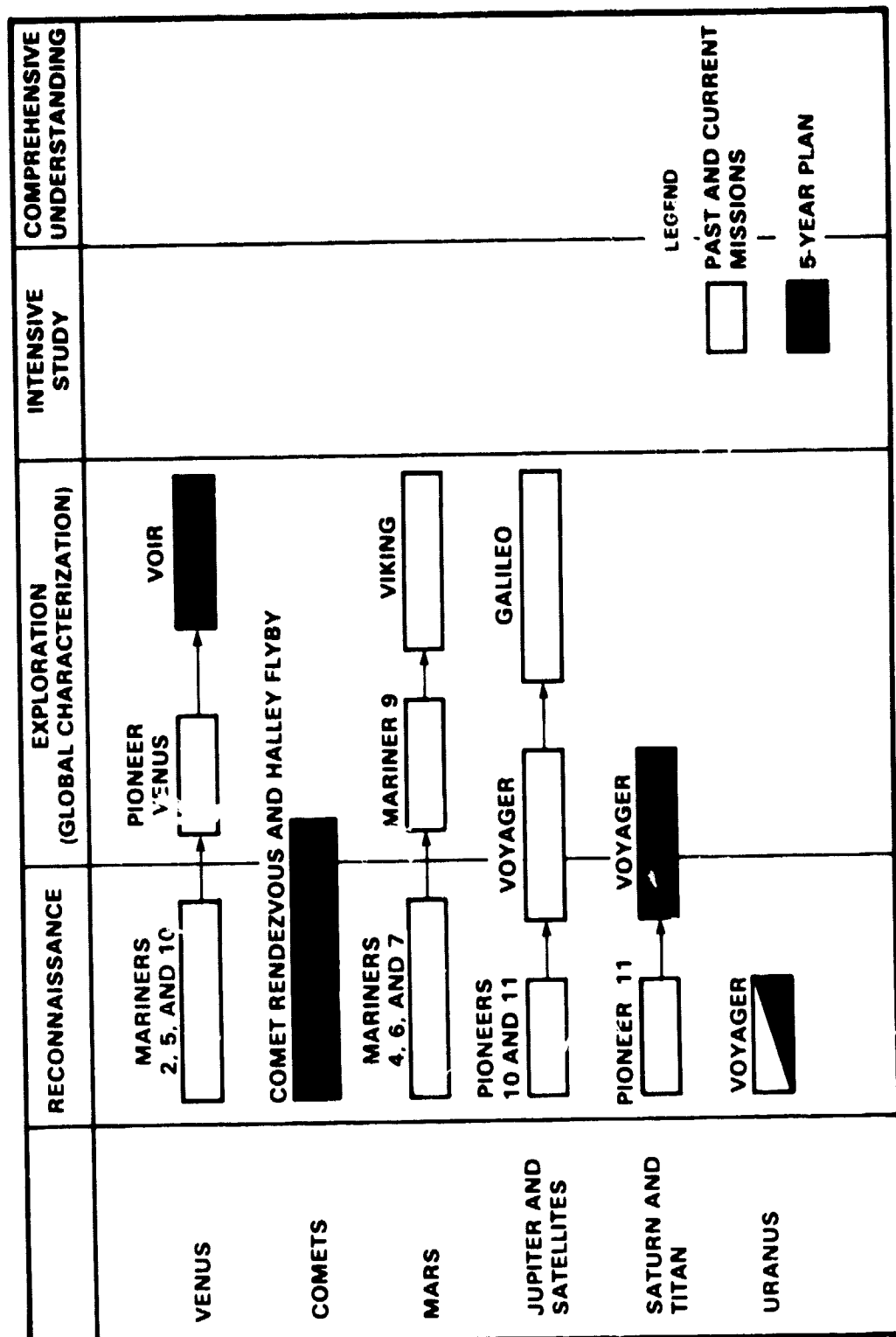
Recent results in solar physics have shown the role of magnetic fields in controlling and influencing the solar atmosphere. We now know that our earlier concept that the solar corona might possess a layered structure, similar to that of a planet, is incorrect. The structure actually is dominated by a collection of individual magnetic arches and loops. We also know that the corona contains regions called coronal holes through which the magnetic field from the surface of the Sun extends into interplanetary space and is the origin of the high-speed solar wind. Coronal holes are most common during solar-cycle minima. Current observations suggest that bright spots observed in the X-ray region of solar spectra may be locations of magnetic fields newly emerging from the solar interior. The frequency of appearance of those spots seems to be inversely related to the solar activity cycle.

We have also recently developed techniques for measuring the motions of the photosphere resulting from waves occurring in the Sun's convective interior. By observing and analyzing the oscillations, we have concluded that the convective region of the Sun extends to greater depths than we had previously believed. The oscillations may also contain information about the change in angular velocity of the convective layer with distance from the Sun's center. That information is of great significance to astrophysics, since the Sun is a star whose details can be observed.

FIGURE 13.  
PLANETARY PROGRAM FUNDING



# **FIGURE 14 — THRUSTS IN PLANETARY EXPLORATION**



Recent results of measurements and theory in space plasma physics indicate that we may have observed the results of the merging of magnetic fields in space. That process, in which magnetic field lines recombine after having been disturbed and opened by plasma processes, can be a source of plasma heating in the laboratory, in space, and in astrophysical processes. We have also observed that charged particles originating in Earth's ionosphere can acquire high energy and be transported into the Sun's geomagnetic tail. We previously had thought that the geomagnetic tail originated only from the solar wind. Thus, we now know that a region far from Earth, beyond the Moon, is intimately connected to Earth's atmosphere.

We also have learned that Earth emits electromagnetic radiation from plasma processes and thus, as Jupiter, is a source of radio noise in the solar system. In addition, we know that plasma processes at high latitudes can produce electric fields parallel to Earth's magnetic field. Those electric fields accelerate charged particles and may be responsible for the production of aurorae.

#### 1. Program Goal

The goal of the Solar Terrestrial program is a quantitative understanding of the physical processes that determine the nature and behavior of solar phenomena; how solar activity controls physical processes in the heliosphere; the structure of the magnetosphere and ionosphere; and the interactions of the magnetosphere and ionosphere with Earth's atmosphere. A characteristic of the Solar Terrestrial program is that it seeks to understand not only the individual regions of the atmosphere and their physical processes, but also the coupling processes that occur.

#### 2. Program Strategy

The strategy of the Solar Terrestrial program is to conduct coordinated theoretical and experimental investigations of solar-terrestrial physics. We emphasize the physical processes that give rise to observed phenomena, and thus the cause-and-effect relationships within the problems under investigation. The investigations typically require simultaneous data from several locations in the solar-terrestrial system and involve a variety of instruments making both remote and in situ measurements. They also require active experiments involving controlled perturbations in the space plasma and the atmosphere.

The focus of our strategy for solar physics research will be development of a quantitative understanding of the physical processes that create and control the flow of electromagnetic and particulate energy and mass from the Sun into the heliosphere. In space plasma physics, our strategy will focus on understanding space plasma, phenomena associated with plasma flow, and the complex interactive processes that control the environments of Earth and other planets for which plasmas play a significant role. We will also emphasize theoretical investigations to understand the basic, predominantly plasma physics processes that are important to solar physics and the solar-terrestrial environment.

Collectively, our theoretical and experimental investigations seek to produce knowledge that will lead us from discovery and definition to an ability to understand and predict solar-terrestrial relationships.

### 3. Status of Current Solar-Terrestrial Research

#### a. Solar Physics Research

Our current solar physics program includes the Solar Maximum Mission (SMM), which was launched in February 1980 and is dedicated to the study of all forms of energetic solar phenomena, especially solar flares and coronal transients. During the currently developing period of maximum solar activity, SMM will conduct unprecedented investigations related to the Sun's release of magnetically stored energy, acceleration of charged particles to high energies, and ejection of mass, and to the creation and cooling of hot plasma during solar flares. We have known for some time that those phenomena produce definite perturbations in the heliosphere and the space environment near Earth; SMM will help us determine the mechanisms involved.

One of the major frontiers of solar and heliosphere physics consists of space away from the ecliptic plane (the plane in which Earth orbits the Sun) and over the Sun's polar caps. Our program to investigate that frontier is the International Solar Polar Mission (ISPM). We will launch ISPM in 1983 to study how the solar wind and the Sun's magnetic field and energetic-particle emissions vary as a function of solar latitude. ISPM will also explore the effects that high-latitude solar features have on solar wind conditions in the ecliptic plane.

#### b. Space Plasma Physics Research

Our present space plasma physics program includes the 3-spacecraft International Sun-Earth Explorer (ISEE) program, which is investigating the dynamic interactions at the boundary between the solar wind and Earth's magnetosphere and at the boundaries between the various regions of the magnetosphere. In 1981, we will launch the 2-spacecraft Dynamics Explorer (DE) to investigate the processes coupling Earth's hot magnetospheric plasma, which is of primarily solar wind origin, with the cool ionospheric plasma, which is of primarily solar ultraviolet origin.

#### c. Synthesis of Results of Solar and Space Plasma Physics

Correlation of SMM and ISEE data will provide considerable insight into the relationship between solar activity and changes in Earth's magnetosphere. Analysis of DE data will provide similar insight into the processes coupling the elements of the magnetosphere and terrestrial atmosphere.

#### d. Spacelab Experiments for Solar and Space Plasma Physics

The Solar Terrestrial program has already scheduled a number of investigations and experiments for flight on Spacelab, including measurements of airglow, infrared radiation, winds in the upper atmosphere, the solar constant, solar magnetic and velocity fields, the hyperfine structure of the chromosphere, and coronal helium abundances. Of special note is a new class of active space plasma experiments in which we will use known stimuli to study basic interactive processes directly. For example, we will use electron beam injections to stimulate the aurora, thereby providing a calibration relating auroral light to precipitation of magnetospheric electrons and gaining new insights into the instabilities, radiations, and emissions created by electron beams in space.

We have recently selected additional investigations for development to expand our research activities in both solar and space plasma physics.

Solar physics instruments selected include an extreme ultraviolet spectrometer, an X-ray telescope and spectrometer, and Lyman-alpha and white-light coronagraphs, while space plasma physics instruments include a wide-angle, Doppler-imaging, Michelson interferometer, an instrument to measure atmospheric Lyman-alpha emissions, an instrument to transmit and receive electromagnetic waves from space plasmas, an energetic ion mass spectrometer, a recoverable plasma-diagnosis package, and a set of magnetospheric multi-probe satellites.

In addition to the principal investigator class of investigations listed above, we have under development two major multiuser facilities for use by Spacelab.

(1) Solar Optical Telescope (SOT)

SOT will be a telescope facility having high resolution and covering a broad spectral range from the ultraviolet through the near infrared wavelengths at angular resolutions down to 0.1 arc second. It will study time-related phenomena of small solar features such as the fine structures of the chromosphere, magnetic flux ropes, spicules, and flare sites -- all of which are considered to be less than 100 kilometers in size.

(2) Chemical Release Facility (CRF)

CRF will be launched by the Shuttle and will make multiple releases of liquids and gases to serve as tracers in mapping magnetic and electric fields, tracking motions of neutral atmospheric constituents, and displaying plasma instabilities, and to serve as test particles for determining particle acceleration, particle entry into specific regions of space, and particle exit from certain trapped regions.

4. Planning Assumptions

This plan assumes the availability of the Space Transportation System, both as a launch vehicle and as a base of operations involving Spacelab and its associated pointing systems. It also assumes that the Office of Space Transportation System's planned development of a Science and Applications Platform will proceed and will provide extended periods of observations in space with "Spacelab-size" instruments.

5. Major New Initiatives

a. Origins of Plasma in Earth's Neighborhood (OPEN)

OPEN's objective is to investigate that portion of Earth's environment where plasma physics determines the behavior of matter. It will require a minimum of four spacecraft making closely coordinated measurements of the major regions of Earth's environment where energy is known to be stored, and of the interchange and dissipation of that energy. OPEN will investigate magnetohydrodynamic processes that are on spatial and temporal scales far greater than those available in Earth-based laboratories, and that therefore must be studied in the natural environment. Those studies will help us understand the plasma processes that are of interest in our Earth-based activities. They are of interest because, through them, energy and matter expelled by the Sun are fed into Earth's environment, where they constitute a highly variable part of our total energy budget.

OPEN will seek to understand how the parts of that closely coupled, highly time-dependent system work together; to trace the flow of matter and energy through the system from input by the solar wind to ultimate deposition into the atmosphere; to understand the physical processes controlling the origin, entry, transport, storage, acceleration, and loss of plasma in Earth's neighborhood; and to determine the role of all those processes in our delicately balanced environment. In doing so, OPEN will place a system of near-Earth satellites in the solar wind, the magnetosphere, the ionosphere, and the magnetotail to make the coordinated, simultaneous measurements required to understand the geospace system.

By studying solar-terrestrial interactions and processes concurrently with the International Solar Polar Mission, OPEN will not only enhance and complement that mission, but will also, in return, benefit from that mission's studies of high solar latitudes, where many solar wind features that influence Earth's magnetosphere may originate.

#### b. Solar Probe

For a full understanding of the processes that drive and heat the solar wind and that accelerate solar energetic particles, in situ measurements will be required. Consequently, we plan to initiate the Solar Probe, which will approach within three solar radii of the Sun's surface. The Solar Probe will also be able to investigate, indirectly, the distribution of matter in the Sun's interior and to conduct basic physics experiments in relativity and gravitation. It will require technology development in the areas of thermal control (since maximum radiation incident on the spacecraft will be equal to 2,500 "Sun's"), telecommunications from within the solar corona, and drag-free systems needed for measurements of the mass distribution in the solar interior and for relativity experiments.

### 6. Other New Initiatives

Additional activities, though smaller in scale, will also contribute significantly to the Solar Terrestrial program's accomplishments. They include continuation of our highly successful Explorer and sounding rocket programs, and new initiatives using the capabilities offered by Spacelab.

#### a. Explorer Satellites

##### (1) Active Magnetospheric Particle Tracer Explorer (AMPTE)

AMPTE will consist of two satellites that will study the dynamic interaction between the solar wind and Earth's magnetosphere by releasing plasma into the solar wind and magnetotail and observing its entry into the magnetosphere.

##### (2) Solar Corona Explorer (SCE)

SCE will study the rotation and evolution of coronal holes as traces of subsurface magnetic fields. It will also study the origin of the solar wind in the inner corona, observe distributions of X-ray bright points as indicators of the emergence of new magnetic fluxes, and provide extremely valuable in-ecliptic observations of the corona to complement the out-of-ecliptic observations the International Solar Polar Mission will make in 1987.

### (3) Plasma Turbulence Explorer (PTE)

PTE will study phenomena associated with the apparently ubiquitous turbulence of plasmas. Current interest centers on determining the distributions of energy in both macro-scale and micro-scale turbulence, and the variation of that distribution with scale size.

We will continue to define, and perhaps initiate, additional Explorer-class satellites during the period of this plan because they are attractive candidates for making measurements in conjunction with the major missions and Spacelab investigations we are developing.

#### b. Spacelab Multiuser Facility -- Tethered Satellite System

The Tethered Satellite System that the Office of Space Transportation Systems plans to develop will provide a capability for deploying and retrieving instrument packages from the cargo bay of the Shuttle. Instrument packages fastened to a thin cable, the tether, will be unreeled by gravity gradients to vertical distances toward or away from Earth as great as 100 kilometers from the Shuttle, where they will make measurements in Earth's atmosphere and ionosphere to altitudes as low as 120 kilometers. Multiprobes along the length of the tether will obtain simultaneous measurements from a number of altitudes, thereby providing discrimination between temporal and spatial variations in the measurements of upper atmospheric and space-plasma processes. In addition, use of a conducting tether and measurements of resulting electrodynamic potentials and currents will yield information on the electrodynamic characteristics of the space plasma environment near Earth.

#### c. Solar Soft X-Ray Telescope Facility

This telescope will provide the high angular resolution at X-ray wavelengths needed for studies related to the physics of the Sun's lower corona, active regions, and flares. We will emphasize its ability to determine the evolution and nature of coronal holes and the magnetic loop structure found in and around active regions.

#### d. Subsatellites

Maneuverable and recoverable subsatellites equipped with appropriate diagnostic equipment will be essential complements to Spacelab. They will observe space plasmas remotely, in an environment free of Shuttle-induced electromagnetic and chemical contamination, to provide spatial and temporal resolution of phenomena in conjunction with Spacelab's active experiments.

#### e. Other Spacelab Programs

During the 5-year period of this plan, we may study and initiate other large-scale Spacelab instruments and facilities if they appear needed to support our planned solar-terrestrial initiatives or to respond to new solar-terrestrial knowledge or increased experimental capabilities.

## 7. Programs for Initiation After 1985

### a. Solar Interior Dynamics Mission (SIDM)

Our current knowledge of the interior of the Sun derives mainly from theoretical reasoning. Because observed neutrino fluxes from the Sun differ significantly from theoretically predicted values, we must conclude that our theoretical premises are incorrect, or that the Sun's interior structure or basic energy-generating processes are different from what we have assumed, or that our experimental data are incorrect. SIDM will provide the first comprehensive data on the Sun's interior. It will investigate the dynamical state of the convective zone below the Sun's surface by observing the oscillations visible on the surface. It will evaluate the depth of the convective zone, the dependence of angular velocity on depth, and the structure of the solar interior.

The observations that SIDM will make are essential to advancement of our understanding of the relationship between the Sun's dynamics and the variations we observe on the surface and in the solar atmosphere. They may lead to a predictive model for solar activity.

### b. Pinhole Satellite

We also are studying a "pinhole" satellite system projected for flight in the late 1980s. This hard X-ray imaging system will provide high-resolution studies of energetic events on the Sun and of the detailed structure and nature of the corona. It will consist of a large, Shuttle-borne, occulting disc filled with thousands of pinholes, and a detector package located as far as 1 kilometer from the disc. To provide maximum scientific value, the system should be fully operational by the next solar maximum (1990) and in time to complement the Solar Probe during the Probe's period of encounter.

### c. Solar Terrestrial Observatory (STO)

As our studies of individual elements of the Sun-Earth system and of the elements' interactions reach maturity, we will be able to link our knowledge of the system to phenomena involving cause-effect chains whose variations may depend on solar activity levels. By developing an understanding of those phenomena, we will be able to predict the effects of perturbations on the Earth-space system. The principal means for studying the phenomena will be extended periods of observation with advanced instruments and techniques to determine and understand the role of the solar cycle, space plasmas, and atmospheric processes in the cause-effect chains.

STO will provide those observations. We expect STO to consist of instrument ensembles that will collect the coordinated data on solar, space plasma, and atmospheric processes necessary for testing previously identified or hypothesized cause-effect mechanisms and for identifying and developing hypotheses related to new chains. The ensembles for early versions of STO will be built up largely from Spacelab principal investigator and multiuser classes of instruments and from instruments designed initially for satellites and rockets. Later versions of STO will include specifically developed instruments. To be able to acquire the complete data set necessary for addressing the complex phenomena involved in solar-terrestrial relations, those later versions of STO may involve more than one observatory and grow large enough that the equivalent of several Shuttle payloads will be required to place them in orbit.

#### d. Close Solar Orbiters (CSOs)

We will design CSOs to exploit the scientific information that the International Solar Polar Mission and the Solar Probe mission will provide. We expect the information and knowledge from those missions to raise scientific questions requiring acquisition of more complete data close to the Sun. This program will provide the means for acquiring those data by placing spacecraft in short-period orbits around the Sun.

#### 8. Schedule and Funding

The phasing of the initiatives in the Solar Terrestrial program is contained in the schedule for the complete Space Science program in Table 9. Figure 15 shows the estimated funding requirements for the first five years of the Solar Terrestrial program, and Figure 16 illustrates how each initiative contributes to the program's overall strategy.

#### G. Life Sciences Program

A unique and important part of the Space Science program is the study of living systems in space. The Life Sciences program consists of two major components, the first of which deals with the effects of the space environment on biological systems, especially humans. For three and a half billion years, living organisms have evolved in, and adapted to, environmental conditions on Earth. Consequently, it is not surprising that terrestrial species react in new and complex ways to unique physical characteristics of space, particularly weightlessness and levels of ionizing radiation that are higher than those experienced on Earth. One part of this component of the Life Sciences program is concerned with the medical, physiological, behavioral, and life support problems engendered by the exposure of humans. The other part deals with the effects of the space environment on lower animals and plants, and with the space environment's utility as a research tool. In both parts, there are significant fundamental and applied research problems.

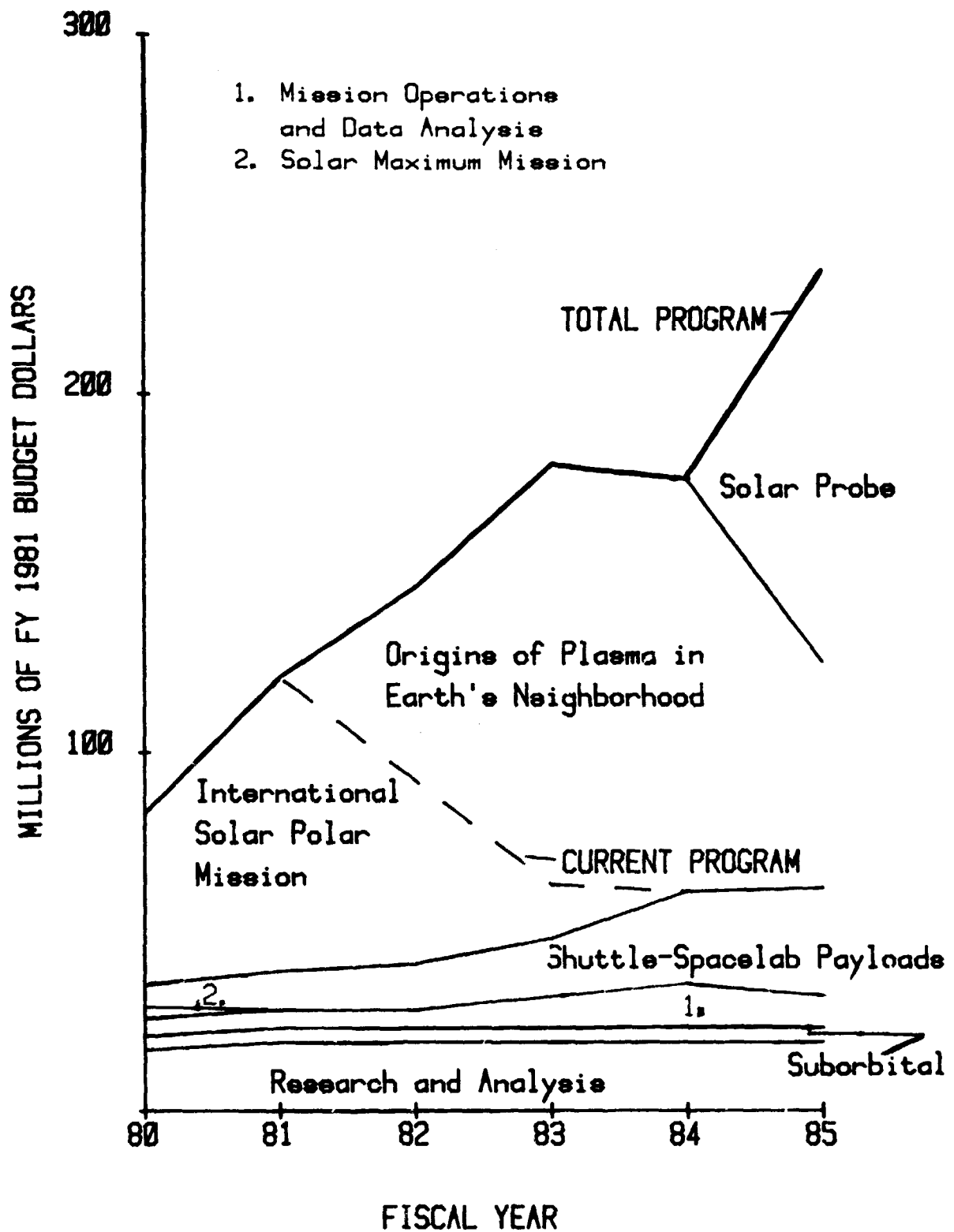
The second major component of the Life Sciences program deals with life in the universe (exobiology). It studies the precursors of life, the origin of life, and the development of complex life forms elsewhere in the universe. Because life is believed to be widespread in the universe, this component studies chemical and biological evolution in the solar system and the galaxy. In doing so, it draws heavily on research into the origin and evolution of life on Earth, where detailed evidence of the story of life is at hand.

##### 1. Program Goals

The major goals of the Life Sciences program are to:

- o Understand and mediate the effects of the space environment on humans so that a varied segment of the population can participate directly in space flight, and to develop the foundation for the extended presence of, and extended operations by, humans in space
- o Increase our understanding of the effects of the unique environment of space on biological processes, and to use the space environment to better understand life processes on Earth
- o Understand the origin, evolution, nature, and distribution of complex life in the universe, and to understand its interaction with the environment.

FIGURE 15.  
SOLAR TERRESTRIAL PROGRAM FUNDING





Each goal is embodied in a program with specific objectives and with specific plans for space flight missions and complementary ground-based research.

The first goal deals with biomedical aspects of the Life Sciences program, and is focused on physiological changes that may adversely affect the performance and health of individuals during space flight or after return from space. One major biomedical aspect involves the changes that occur rapidly after entry into the space environment: motion sickness, fluid redistribution within the body, and associated hormonal and biochemical changes. A second major aspect becomes significant for exposure to space over a period of time: demineralization of bones, atrophy of muscles, potential changes from the cumulative effects of ionizing radiation, and changes related to the behavioral sciences. A third major aspect addresses the development of life support systems for short-term and long-term exposure of humans to the space environment.

The second goal focuses on fundamental questions of space biology, and its major objectives are subsumed under the discipline of gravitational biology. Space flight offers a unique opportunity to explore the response of animals and plants to the absence of gravity. To some degree, all living systems are influenced by gravity at subcellular, cellular, organ, or whole body levels. So, changes in biochemical and biological functions revealed during space-biology flight experiments will lead to a better fundamental understanding of the degree to which gravity is important in the terrestrial environment, and of gravity's role in biological evolution. That knowledge will, in turn, contribute significantly to our understanding of the important practical problems of human physiology and controlled ecosystems in space, since the mechanisms by which living systems change in weightlessness will progressively be uncovered.

The third goal deals with the origin and evolution of life and seeks an understanding of how biology fits into the larger question of cosmic evolution. It begins with the formation of the planets, then progresses to the formation of organic compounds, the process of biogenesis, the evolution of self-replicating systems, and finally the formation of living cells and the earliest multicellular organisms. Of profound importance, also, is the interaction between an evolving planet and its evolving biota. For example, how do biological processes, human-induced and natural, alter the very nature and evolution of a planet, and vice versa? The third goal also addresses the nature and distribution of complex life in the universe. Significant deliberations over the past two decades have developed an increasingly serious debate about the existence of extraterrestrial life in general, and of intelligent extraterrestrial life in particular. These matters excite the curiosity, the imagination, and the exploratory spirit of many scientists of all persuasions — indeed of people from all walks of life.

## 2. Program Strategy

Our strategy for meeting the three goals of the Life Sciences program includes flight and ground activities, fundamental and applied science, and near-term and long-term objectives.

### a. Flight and Ground Activities

Changes in human physiology during flight in space are large enough to cause immediate problems and potentially to lead to future problems. Those

problems must be resolved because they could limit the ability of humans to live and work in space. A significant amount of ground research must precede the testing of specific hypotheses in space. We also conduct research to develop effective designs for space systems and long-duration space missions.

This biological and life-support systems work receives the largest share of our life sciences funding.

#### **b. Fundamental and Applied Science**

In contrast to the relatively applied nature of our research related to humans in space, our space biology and exobiology work concentrates on scientific questions of fundamental importance. By what mechanisms does gravity affect living systems? What are the effects of high-energy cosmic particles on living systems? How did life begin? Why did it evolve as it did on Earth? Has it evolved elsewhere? To what degree of complexity? Can we detect it? The fundamental importance of those questions is so great that the search for answers to them is a central and exciting component of the Life Sciences program. They are intrinsically interesting. In addition, they promise to help us understand the practical problems humans face in space and the interactions between biology and our planet, Earth.

#### **c. Near- and Long-Term Objectives**

The Life Sciences program embraces both near-term and longer-term objectives related to all of the program's goals. The near-term objectives are clear and occupy a significant part of the program. The longer-term objectives are equally important, dealing as they do with the conditions under which humans can remain in space for long periods of time and with the story of life in the universe.

### **3. Current Program**

The Life Sciences program currently is divided into two major categories: Flight Experiments and Research and Analysis. The Research and Analysis category deals primarily with ground-based supporting research and technology.

#### **a. Flight Experiments**

The most important single event during the 5-year period of this plan will be the flight in 1983 of SL-4, the first Spacelab dedicated to life sciences. SL-4 will be preceded by several Shuttle missions on which life science experiments will be only part of the payload. After 1983, Spacelab missions dedicated to the life sciences will be flown at least every eighteen months. We will develop the payload for each of those missions under our Life Sciences Flight Program, and each payload will contain both medical and biological experiments. We are currently developing ground-based facilities and over two dozen items of laboratory equipment needed by multiple users. We have tentatively selected approximately 90 investigations to conduct on the Shuttle and Spacelab flights, and have definition studies for them in process.

#### b. Research and Analysis

Our basic research and analysis program consists of medical and biomedical investigations in a wide range of problem-oriented areas, basic gravitational biologies, and life support systems. We try to pursue each of those disciplines in a way that supports the goals and schedules of the overall Life Sciences program.

The emphasis of our research related to the nature and distribution of life in the universe is on understanding the mechanisms involved in the synthesis of essential biomolecules and on the environment in which the synthesis takes place. The understanding we gain will help us refine our estimates of the probability of similar occurrences beyond Earth.

This research is conducted both in our in-house laboratories and through contracts and grants with universities and industry.

#### 4. Major New Initiatives and Program Thrusts

Our planned initiatives for the 1981 through 1985 period constitute a program focused on the particular areas in flight experiments and ground-based research that will move the life sciences forward on a broad front and in an integrated fashion. They will provide the thrusts to the Life Sciences program discussed in the paragraphs that follow.

##### a. Increase in Emphasis on SR&T Flight Projects

As Shuttle and Spacelab flights become increasingly available for life science investigations, we will place more emphasis on readying ground-based research for in-flight experimentation. We have started trying to interest and involve in our program an entirely new community of life scientists, and they are not familiar with the constraints that exist or the specific opportunities that will be available. Therefore, we plan to devote a larger portion of our SR&T (space research and technology) budget specifically to provide early support for investigators who have proposed scientifically valid in-flight experiments that, because of the investigators' lack of experience, are not mature enough for mission assignment. We will also actively solicit basic ground research that will ultimately require access to space flights.

##### b. Increase in Use of Shuttle and Spacelab

We have issued one Announcement of Opportunity (AO) for life science investigations. Because the large response to that AO showed that the scientific community needs many flight opportunities, we plan to increase the number of experiments on each Spacelab dedicated to the life sciences from the 15 to 20 level to the 25 to 30 level. Increasing the number of experiments per payload will provide the additional benefit of more cost-effective use of the Shuttle-Spacelab system without any overloading of the crew, the payload specialists, or the system. We will also considerably reduce the cost per experiment by forming payload groupings that will use Spacelab's resources -- power, energy, volume, weight-carrying capability, recording equipment, and payload specialists -- to the fullest extent commensurate with efficient and safe operation.

We have recommended for definition studies approximately a quarter of the 371 proposals we received in answer to the AO. Those proposals have a high level of scientific merit and tentatively have been judged to be compatible with the Shuttle-Spacelab system. We can develop and fly at least half of the approximately 90 recommended experiments during the next five years only if we use the Shuttle and Spacelab to the maximum possible extent.

We will undertake the next phase of basic development and design of experiment payloads in connection with experiments proposed for the second and third Spacelabs dedicated to the life sciences. That phase will involve optimizing payloads by combining experiments, subjects, or specimens, and by optimizing equipment use within a payload.

c. Increase in Mission Rate

To accommodate, within the next five years, the large number of experiments of high scientific merit proposed in answer to the AO, we will have to decrease the time between Spacelab flights dedicated to the life sciences from the 18 months between the first and second ones to one year between the second and third ones and all subsequent pairs of flights. To do so while maximizing payload flexibility and reducing the time between experiment selection and flight, we will have to restructure our planning activities related to the selection, definition, re-evaluation, development, and flight of experiments. We will also have to develop procedures to support an increased launch rate and to provide capabilities for making late changes both in the content of individual experiments and in the composition of the total payload complement of experiments.

d. Development of Large Primate Facility (LPF)

Large primates are excellent surrogates for humans in many physiological and medical areas we are studying. Consequently, to address a major objective of the Life Sciences program -- namely, to understand and develop an ability to mediate the effects of the space environment on humans -- we plan to design, develop, and fly in the Spacelab pressurized module an LPF that will not only increase our understanding of the effect of space on biological processes, but will also help us verify our models for relating the results of tests on animals to potential results with humans. A capability to perform this kind of research does not now exist.

The LPF and its transporter will accommodate and provide full care and maintenance for primates weighing as much as 20 kilograms. The LPF will occupy a Spacelab double rack. Its life-support system will manage its atmosphere, including odor control, and will provide food, water, light, passive waste management, isolation, and instrumentation.

The initial use of the LPF will be in cardiovascular studies conducted with implanted biotelemetry systems. Miniaturized sensors will be implanted in primates to measure their blood flow, blood pressure, and cardiac performance to directly assess the mechanisms their bodies use to adjust to space flight. Within the LPF, the primates will be unrestrained.

Our next action related to the LPF will be to initiate definition studies to refine and upgrade our present conceptual designs. We then will conduct tests and evaluations with mockups on the ground to assess the validity of our designs and the compatibility of the proposed facility with the primates to be accommodated.

#### e. Development of Large General Purpose Centrifuge

The scientific community is developing an increasing interest in basic research on phenomena involving interactive connections between vestibular, visual, and other neuronal systems of the body. It has recommended that we try to develop means to reduce masking stimulations such as vibrations, acceleration due to gravity, and the Coriolis effect while making all other stimuli the same for both weightless and controlled-gravity specimens. To provide those means, we plan to design, develop, and fly in Spacelab a large, general purpose centrifuge.

The centrifuge will be 12 feet in diameter and will constitute a major step forward in our ability to conduct biomedical research in space. It will provide the stimuli of normal Earth-surface (1-g) gravity and a range of gravity gradients and angular accelerations. Its large diameter will reduce the confounding effects of Coriolis forces and provide room for many specimens at its rim. The large diameter also will provide a capability for testing specimens simultaneously at a range of gravitational levels by positioning them along the centrifuge's arms.

#### f. Development of Advanced Space Suit

U.S. space suits, including the current suit for Shuttle crew members, have been designed to maintain a maximum internal pressure of about 4 psia (pounds per square inch, absolute). The pressure in the living and working areas of the Shuttle will be ambient atmospheric pressure, 14.7 psia. Consequently, before embarking on extravehicular activity (EVA) or on work in the Shuttle's unpressurized cargo bay, an astronaut will have to breathe pure oxygen for about three hours to eliminate enough nitrogen gas from the tissues of his body to avoid dysbarism, or diver's bends, which is caused by the formation of nitrogen bubbles within the body. A transition in pressure from 14.7 to 8 psia will not cause bends. Consequently, we plan to develop and demonstrate, for operational use with the Shuttle, an 8-psia space suit.

Our approach to developing the 8-psia suit will be to modify the current Shuttle suit, the Extravehicular Mobility Unit (EMU), using advanced technology concepts to improve joints and their configurations, reduce leakage, increase the life of bearings, and develop manufacturing techniques for both soft and hard goods to be used in the suit. We will evaluate all available concepts and select the best approach to the 8-psia suit that doesn't sacrifice mobility, EVA duration, or ease of use.

#### g. Development of Life in the Universe Program

We plan significant new activity in our Exobiology program that will expand it into a comprehensive and complete program, Life in the Universe. Our Exobiology program addresses two elements of the complete program, chemical evolution and origins of life, but does not address two other important elements, the interactions of biogenic elements (carbon, nitrogen, hydrogen, oxygen, etc.) that occur before the formation of small organic molecules, and the evolution of life after primitive life forms first appeared.

Our past and current research has made us realize that we need to understand biogenic element interactions to be able to identify the environments and mechanisms that can produce the synthesis of organics essential for life. To gain that understanding, we will have to look far back in time. Consequently, we will initiate investigations in the chemistry of comets, meteorites, asteroids, and the interstellar cloud.

Our research has also made us realize that our program would be grossly incomplete unless we broaden our perspective to include the evolution of primitive life forms into complex life forms. Consequently, we will try to determine how planetary, solar, and astrophysical events can affect the evolution of higher forms of life. We will seek to define "habitable zones" (environments) or conditions under which life, as we know it, could evolve.

The final element in the scenario for our Life in the Universe program is the one that excites the imagination of people everywhere. It concerns life at the apex of the pyramid of life forms -- intelligent life. We will make a serious attempt to develop technology for, and actually conduct, a search for extraterrestrial intelligent life.

#### h. Undertaking of Other Initiatives

The dynamic character of this nation's civil space program and of the life sciences portion of that program dictates a periodic reassessment of goals and objectives. For example, should the emphasis of the Life Sciences program move away from human and medical aspects toward space and terrestrial biology? What emphasis should be placed on exobiology? What level of resources should be applied to technology advances in life support systems?

Advanced studies can and should exert considerable leverage on the strategic planning and decision making related to those types of questions. Consequently, we plan to conduct studies in the following five areas:

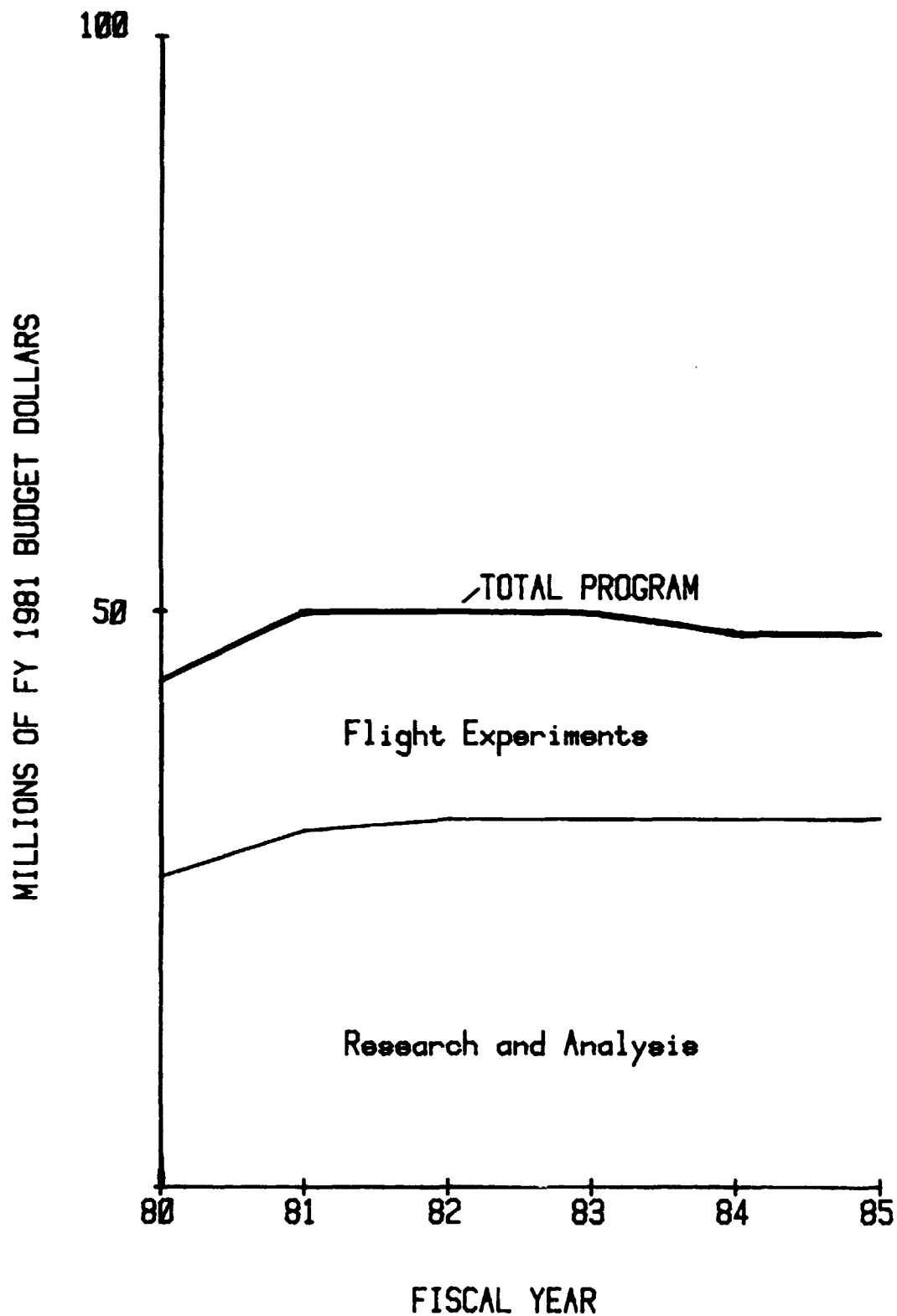
- o Program Planning -- We will use a systems analysis approach, where possible, in helping to provide overall program planning.
- o Medical Treatment in Space -- We will develop methods for maintaining the health of, and for treating, crew and passengers during flight in space. Current provisions for providing those services are limited.
- o STS (Space Transportation System) Habitability -- Studies of sleep, exercise, nutrition, and factors influencing the compatibility of Shuttle crews and passengers are needed for evaluating and improving the performance of humans during flight in space.
- o Vestibular Sled -- A study is needed to establish the design requirements for a manned sled for experiments aboard the Shuttle. Currently, we have some modest experiments aboard an ESA payload, but they are inadequate to meet NASA's needs.

- o Global Terrestrial Ecology -- In this study activity, we will seek to develop an ability to examine, possibly using modeling and terrestrial measurements, the interaction between Earth and its biology and between the lithosphere, the hydrosphere, the atmosphere, and the biosphere.

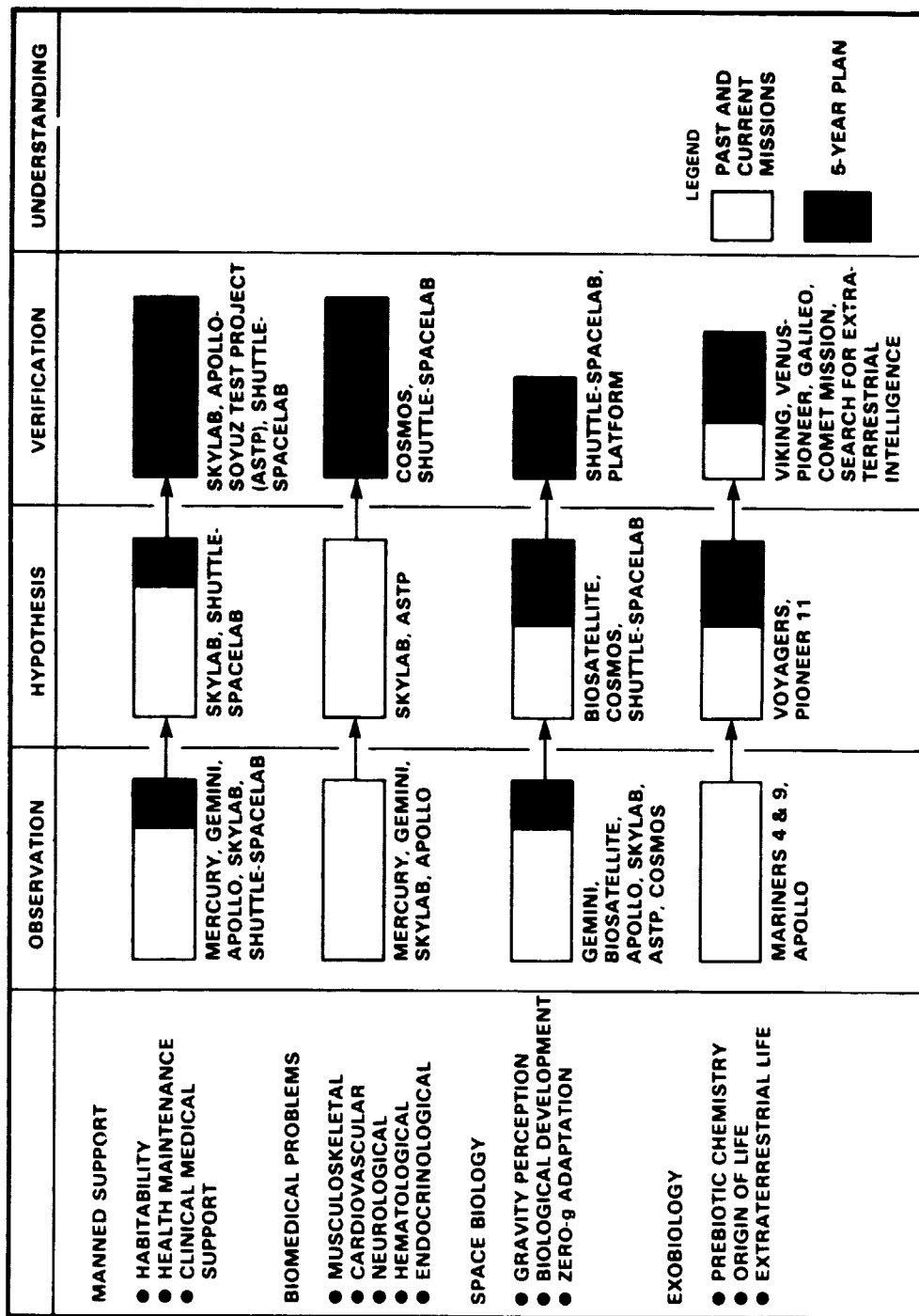
#### 5. Funding

Figure 17 shows the funding requirements for the Life Sciences program, and Figure 18 illustrates how the various activities in the program contribute to satisfaction of the program's goals.

FIGURE 17.  
LIFE SCIENCES PROGRAM FUNDING



# **FIGURE 18 — THRUSTS IN LIFE SCIENCES**



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## V. SPACE AND TERRESTRIAL APPLICATIONS PROGRAM

As mentioned in the Introduction to this report, the Space and Terrestrial Applications program is in a state of rapid evolution. Consequently, much of the information that follows will be out of date by the time the report is published. If you are working in any applications area and current information is important to your work, you are therefore urged to request that information from the Office of Space and Terrestrial Applications.

The Space and Terrestrial Applications program has three principal elements:

- o Observation and study of Earth from space to understand and forecast environmental behavior, to assess the productivity of Earth's surface for both renewable and nonrenewable resources, and to develop a "standard" model of the dynamic Earth
- o Performance of research in the space environment to clarify materials processes and to explore feasible and advantageous processing that can be carried out in space
- o Development of selected technology for telecommunications satellite systems that will be more effective and efficient, and provide higher capacity.

Collectively, these three program elements apply NASA's space capabilities to solve many challenging problems related to human welfare and improvement of the quality of life on Earth.

In the last several years, we have successfully demonstrated that space techniques and observations can make substantial contributions to telecommunications, assessment of agricultural productivity, land-use changes, and research in processes related to weather forecasting, climatic fluctuations, human-caused changes in the environment, tracking of severe storms, and motions of Earth's crust.

### A. Program Thrusts

For the 5-year period of this plan, the major thrusts of the Space and Terrestrial Applications program will be to:

- o Develop jointly with the Department of Defense (DOD) and the National Oceanic and Atmospheric Administration (NOAA) a national satellite system for limited operational demonstration of ocean monitoring capability
- o Develop jointly with NOAA the next generation of weather satellites
- o Participate in the National Climate Program by initiating the space segment of a climate observing system
- o Develop jointly with the Department of Agriculture improved capability to forecast production of major agricultural commodities in primary producing areas

- o Expand space capability for geological delineation of surface features for resource assessment
- o Develop, over a period of 10 to 20 years, models of contemporary motion (rate and direction) of major tectonic plates; model accumulation of crustal strain in seismically active areas; and identify causative relationships for changes in Earth's polar motion and rotation
- o Renew development of communications-satellite technology, pioneering new frequency bands and developing large spacecraft antennas with multiple beams and spaceborne switching systems
- o Initiate experiments in materials processes using Shuttle-Spacelab capabilities
- o Develop methods for rapidly and effectively transferring to potential users the techniques, technology, and information resulting from NASA activities.

#### B. Program Content

Figure 19 shows the funding requirements for the Space and Terrestrial Applications program. The sections that follow describe our plans for the three principal program elements described above and also for our Technology Transfer activity.

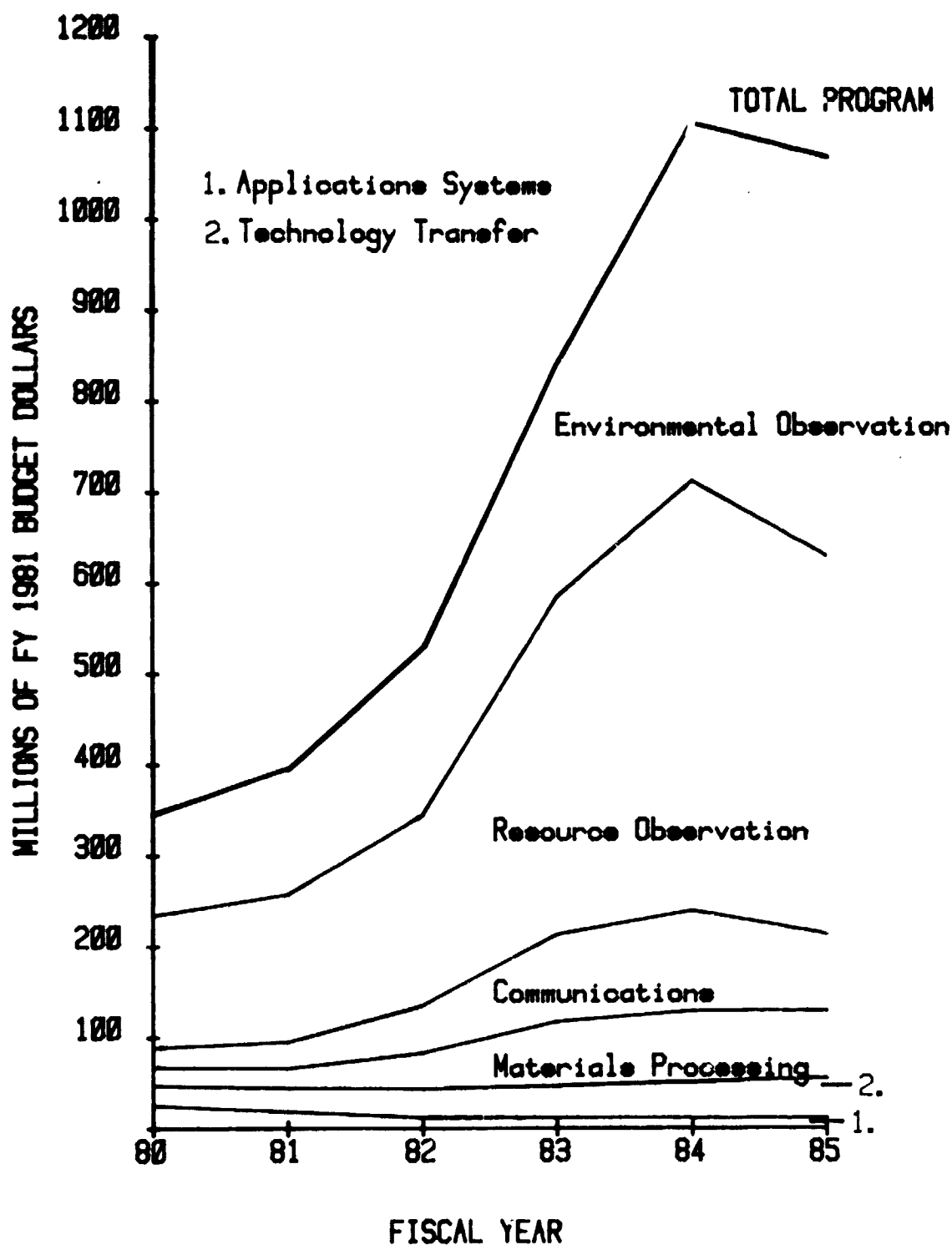
Applications Systems, for which the funding requirement is shown at the bottom of Figure 19, is not discussed elsewhere in this report. It is shown separately in the figure because it supports other NASA programs, as well as major segments of the Space and Terrestrial Applications program. Its principal function is to provide flight support with aircraft that serve as test beds for many kinds of experiments and as platforms for instruments that must be operated at altitudes above usual aircraft altitudes.

#### C. Earth Observation: Environment

The Environmental Observation program is concerned with the fluid system that surrounds our planet. It applies observations from space and other space techniques to increase our ability to understand and forecast the behavior of that fluid system. Viewed from space, the fluid system is comprised of natural layers named, starting from the top, the thermosphere, the mesosphere, the stratosphere, and the troposphere, and then, on Earth's face, the surface water, principally the oceans and lakes. While each layer is unique, the interactions of the layers with each other and with Earth's land masses produce the complete environmental system that is vital to life.

Our environment is a very complex system. To understand it, we must understand both the nature of each layer and the interactive processes that tie the layers together, and must then integrate our understanding of all those individual components into a consolidated understanding of the total system. Consequently, the Environmental Observation program is composed of two major subprograms, Atmospheric Processes and Oceanic Processes. Each subprogram has two functions -- performing research and development to understand the environment and assisting the operational agencies that forecast environmental changes.

FIGURE 19.  
SPACE AND TERRESTRIAL APPLICATIONS PROGRAM FUNDING



## 1. Goals and Objectives

This program's eventual goal is to define, develop, and demonstrate key aspects of a global environmental observation and information system.

Its objectives over the next five years are to:

- o Define and develop the Oceanic Processes subprogram into a comprehensive research and operational support activity
- o Define, in cooperation with user agencies, next-generation operational systems
- o Strengthen the program's scientific base
- o Implement a planning system that yearly identifies and supports new thrusts and initiatives
- o Increase involvement of researchers and users in the program
- o Define and conduct an integrated modeling and measurement effort
- o Move from single purpose satellites toward integrated multidisciplinary payloads and missions
- o Define program policy and goals for 1990 and the end of the century with alternate approaches to achieve the goals.

## 2. Program Strategy

Our strategy for accomplishing the program's goals and objectives will consist of identifying problems, developing an understanding of the problems (reviewing and strengthening the scientific bases involved), developing missions, and developing operational systems.

## 3. Planning Assumptions

We assume that the program will continue to support the operational agencies (NOAA, DOD, Environmental Protection Agency (EPA), etc), that research will be a major activity in the program, and that increased funding will be available both to provide research missions for sensor development and to enhance our Applied Research and Data Analysis (AR&DA) capabilities.

## 4. Atmospheric Processes

The goals of the Atmospheric Processes subprogram are to increase our knowledge and understanding of Earth's atmosphere and to improve our ability to predict its future state. We will achieve those goals through research and development to improve measurement and analytical techniques, improvement and use of remote sensing capabilities, and assisting operational agencies, including NOAA, DOD, and EPA, to improve forecasting and assessment capabilities.

For the purposes of this plan, the distinct characteristics of the dynamic, chemical, and radiative processes involved make it convenient to discuss the atmosphere as consisting of two layers, the upper atmosphere (mesosphere and stratosphere) and the troposphere, with the understanding that there is appreciable coupling between the layers.

#### a. Upper Atmosphere

The upper atmosphere is a vital link in the overall environmental system. It contains the ozone layer that filters ultraviolet (UV) radiation from the Sun. Changes in ozone concentration can affect UV flux at the ground, with potentially harmful effects on life. Also, radiation absorbed and emitted in the upper atmosphere is a key factor in atmospheric circulation patterns and energetics that influence Earth's weather and climate. The upper atmosphere may be the principal region coupling solar phenomena to lower atmospheric weather.

NASA's upper atmosphere activities stem from Congressional mandates in the 1976 NASA Authorization Act and the Clean Air Act Amendments of 1977 to implement a comprehensive program of research, technology, and monitoring related to the upper atmosphere. Our objectives are to improve our understanding of, and to assess threats to, the upper atmosphere. We will focus on developing a solid knowledge of the physics and chemistry of the region and on increasing our ability to assess potential changes in it, particularly in the ozone layer. Our objectives also include the more distant goal of aiding regulatory decisions.

Over the next five years, we will emphasize determination of the production, loss, and flow of chemically and radiatively active constituents such as ozone, and measurement of related dynamic processes and solar inputs. We will continue to derive our research base from theoretical studies, laboratory measurements, and field measurements from ground, aircraft, balloon, and rocket platforms. We will emphasize multidimensional models able to use and complement global data from satellites.

In space, payloads in the Shuttle will test advanced techniques for measuring winds with interferometers and advanced microwave techniques for future free-flyer missions. Shuttle payloads also will study solar flux and properties of the atmosphere. An atmospheric LIDAR and the Cryogenic Limb-Scanning Interferometer and Radiometer to be carried by the Shuttle will extend into space the advantages that active remote sensing provides and will expand the capabilities of passive thermal-emission sensors. Analysis of data from Nimbus 7 will provide new insight into the nitrogen-ozone cycle, and the Halogen Occultation Experiment (HALOE) will provide the first global data on the chlorine-ozone cycle. Data from Nimbus, the Stratospheric Aerosol and Gas Experiment (SAGE), and HALOE will contribute to the data base required for study of ozone trends. The Upper Atmosphere Research Satellites (UARS) will build on studies of specific processes from our research program and earlier satellite missions. They will provide the comprehensive global study of the chemical composition, dynamics, energetics, and couplings of the upper atmosphere that we must have to be able to consolidate our knowledge into a form useful for understanding and predicting the environment.

#### b. Troposphere

The troposphere, the surface layer of Earth's atmosphere, extends to altitudes of about 10 to 15 kilometers. Because the troposphere contains 90 percent of all atmospheric gases, all the weather and storms, and most pollution episodes that affect society, we plan to develop methods to measure and predict its characteristics, to develop techniques to monitor remotely its state over a wide range of spatial and temporal scales, and to conduct research into the extremes in atmospheric dynamics that cause severe storms.

### (1) Global Weather

The global weather portion of the Atmospheric Processes subprogram develops and improves the sensing abilities of meteorological satellites. To provide an understanding of atmospheric processes and to improve the accuracy of mid-range (2- to 14-day) weather forecasts, it also develops and improves techniques for extracting meteorological information from remotely acquired data. It supports the Global Atmospheric Research Program (GARP) and the GARP Global Weather Experiment (GWE). NASA's GARP work emphasizes special observing systems, use of remote sensing data to improve forecasts, and research on global-scale numerical models for use in forecasting weather. Our research over the next five years will address improvements in the physics of our models, assimilation of satellite data, assessment of the effect of satellite data on forecasting capabilities, simulation studies to optimize future observing systems, and analysis of GWE data sets.

### (2) Operational Satellite Improvement Program (OSIP)

OSIP seeks to improve remote sensors and ground-based data processing systems. We plan to make the first temperature soundings from geosynchronous orbit and to develop an operational satellite-mounted ozone sensor for NOAA. Our AR&DA will continue studies that address advanced sensors (including sensors to measure winds and pressure remotely), improvement in the long-duration performance of instruments, a zero-gravity fluid-dynamics experiment, methods to improve retrieval of data from cloudy atmospheres, and extensive development of numerical models in collaboration with researchers at academic institutions.

Joint NASA-NOAA studies to improve weather forecasting abilities will define an improved operation flight and ground system. The flight system will update the characteristics of the current Tiros and Geostationary Orbit Environment Satellite, and will be compatible with the Shuttle.

### (3) Air Quality

The air-quality portion of our tropospheric investigations endeavors to: use data acquired in space to understand the large-scale dynamics, transport properties, and related chemistry of the troposphere; improve our current models; provide EPA with advanced techniques for monitoring and forecasting, on a regional scale, pollutants such as sulfates, nitrates, "hazy blobs," ozone, and aerosols; define and develop advanced sensing techniques and systems; and initiate, with the National Science Foundation (NSF), joint field experiments related to development and demonstration of systems to make global measurements of parameters such as concentration of carbon monoxide in the troposphere and transport of pollutants between Earth's hemispheres.

Our major air-quality research activities will continue to address the principal process governing the global systems related to the carbon-nitrogen-ozone cycle and the sulfur-ammonia-trace metal-aerosol cycle, and the relative roles that transport, transformation, and removal processes play in governing the behavior of regional scale polluted air masses. Modeling and data analysis tasks we will pursue during the next five years include development of global tropospheric chemistry and transport models, analytical studies of tropospheric chemical cycles, and reduction and analysis of data from a number of cooperative field studies and the Measurement of Air Pollution from Shuttle experiment.

We will continue to participate in cooperative activities such as EPA's Persistent Elevated Pollution Episodes and Northeast Oxidant studies and the NSF-funded GAMETAG global aircraft measurement study.

In the area of technology development, we will emphasize the continued development of both active and passive remote sensors for tropospheric monitoring. A new, longer term study will define an air-quality satellite system.

#### (4) Severe Storms

The troposphere is the most dynamic of the atmospheric layers relative to life on Earth, as is evident in the severe storms that frequent all parts of our planet. The goals of our severe storms activities are to increase basic understanding of storms and to help the responsible weather-forecasting agencies, primarily NOAA, to improve the accuracy and timeliness of their severe weather forecasts and warnings. The activities have four objectives: to understand severe storm development, to demonstrate and verify space-derived observations, to develop sensors, and to develop models that will improve our ability to predict storms.

During the next five years, we will emphasize transfer of space-derived forecasting aids to users, comparison of mesoscale models, understanding of the physics relating atmospheric state and flow to local-weather observables, and study of full-scale storm activity, including observation of its microphysical and electrical characteristics. We will use flights of high-altitude aircraft over severe storms as aids in developing methods for quantifying the relationships expected to be found in future observations from space, and in developing fast, simplified models for use in predicting storms in near real time.

Several projects are essential to the success of those activities. One is analysis of data we collected in a large-scale field demonstration of NASA technical capabilities for observing and modeling storm development. That demonstration involved many non-NASA weather research groups. A planned project is assessment of the Visible-Infrared Spin Scan Radiometer Atmospheric Sounder's value for measuring and understanding the environments of severe storms, and its ability to measure temperature and moisture profiles from geosynchronous orbit. A longer term activity will be definition of a severe storms satellite system.

#### 5. Oceanic Processes

The Oceanic Processes portion of the Environmental Observation program is concerned with the surface water of Earth's fluid system. The oceanographic community's goals are to observe and ultimately to predict the oceans' general circulation; transport of heat and trace elements; surface environment, including winds, waves, and surface currents; exchange of heat, water, and momentum with the atmosphere; and distribution of marine organisms, including fish and mammals.

To those goals must be added the providing of the support required by operational agencies such as NOAA, the Coast Guard, the Departments of Defense and Energy, and EPA. All those agencies need to observe the ocean, or activity in or on the ocean, particularly within the economic zone out to 200 miles offshore.

##### a. Study Areas

Our investigations of oceanic processes address the five subjects discussed below.

(1) Atmospheric Boundary Layer

Our studies of the marine boundary layer seek to provide objective means for removing the directional ambiguity from scatterometer-derived data on surface winds and for assimilating information on those winds into numerical weather forecasting models. We may possibly have to reformulate our numerical models so that they can more efficiently use scatterometer measurements, which come at different times than conventional observations do.

(2) Oceanic Circulation

In our studies of circulation in the oceans, we will seek to use geoid data, altimetry, and information from spacecraft whose orbits are precisely known to define sea-surface topography and to estimate absolute surface geostrophic currents associated with both the general circulation and the mesoscale variability of the oceans. Using existing, but incomplete data from Seasat and the Geodynamic Experimental Ocean Satellite-3 (GEOS-3), we will develop and demonstrate our ability to measure surface topography and to estimate surface currents in preparation for a new altimetry mission.

(3) Air-Sea Interaction

Over the next couple of years, we will continue to try to determine whether we can use remotely sensed data to study air-sea interactions. We will particularly use radiometer data to seek unambiguous measurements of surface temperature, foam, and rain. We will also seek an explanation of surface features seen in imagery provided by Seasat's synthetic aperture radar. The results from this work will be particularly important to future weather and climate projects.

(4) Sea and Glacier Ice

We will study sea and glacier ice as part of a future program to observe them from space. The monitoring of changes in sea and glacier ice fields is important to the study of ice dynamics, weather and climate, and ocean transportation.

(5) Coastal and Inland Waters

Studies using space instruments to observe coastal and inland waters are particularly important to one of NOAA's missions. They will contribute to an understanding of life in the oceans and lead to wiser use of ocean fish stocks. They depend, in part, on interpretation of color imagery of the oceans, especially with regard to an ability to discriminate between materials, both organic and inorganic, dissolved and suspended in the waters. We are seeking to understand the relative contribution of marine organisms to color signals, and to estimate the productivity of open ocean areas. We plan to commence exploring ways to combine the Advanced Very High Resolution Radiometer and the Coastal Zone Color Scanner into a single versatile instrument for use in these studies.

b. Development Approach

We will work closely with NSF, NOAA, and the Office of Naval Research (ONR), to ensure that we have a good fundamental basis for interpreting remotely sensed signals, and also that those interpretations will ultimately

contribute to our understanding of oceanic processes. To help satisfy that objective, NASA scientists will work closely with colleagues in the oceanographic community and participate in their programs and experiments.

As NASA's techniques and instruments mature, we will transfer the underlying technology to NOAA and DOD, the primary operators of ocean-observing systems. Our altimeter and scatterometer instruments are nearly ready for operational use, and our Coastal Zone Color Scanner is not far behind. We are continuing development of both the Synthetic Aperture Radar and the Scanning Multichannel Microwave Radiometer with every expectation that they too will contribute to operational systems.

We will strengthen the bridge between the worldwide oceanographic community and NASA's remote sensing organization; emphasize analysis of existing space-derived data from GEOS-3, Seasat, and Nimbus-7; develop improved techniques for collecting data from ships, aircraft, and the Shuttle; and transfer proven techniques for observing the seas to operating agencies. Theoretical studies, laboratory measurements, and field studies using ground, aircraft, and space platforms will continue to provide the research base for interpretation of oceanic processes.

We will use the Shuttle-Spacelab system in evaluating instruments and techniques that we develop to make new or more accurate measurements of processes at work in and on the surface of the oceans. Check-out and assessment on the Shuttle will be preceded by a balanced program of theoretical studies, instrument and algorithm development, and laboratory and airborne tests, and will lead to decisions as to whether the instruments and techniques should be incorporated into free-flying oceanographic spacecraft. An additional benefit of this activity will be the availability of a set of Shuttle-compatible measurement systems for use both in supporting specific oceanographic experiments and programs and in responding to predictable (e.g., seasonal and local) targets of opportunity.

Complete delineations in research on oceanic processes depend on integration of observations from space with surface and subsurface observations, which can serve to calibrate some space observations (e.g., temperature), can complement other observations (e.g., pressure -- to go with surface winds), and can provide data not obtainable from space (e.g., subsurface temperature and currents). Surface and subsurface observations possibly could even be an integral part of a remote sensing system. Consequently, we will cooperate with NSF and ONR to investigate ways to track and interrogate surface and subsurface platforms, and to link shipboard observations to satellite data.

## 6. Climate

The ability to understand and anticipate climate trends and anomalies can have a major influence on national and regional planning related to agriculture, energy, natural resources, transportation, and construction. NASA's climate activities are evolving as a major part of the National Climate Program, which is coordinated by NOAA. They emphasize application of space observations to help create an understanding of the key environmental processes that control the state and change of climate, and of the interactions among those processes.

NASA's climate research addresses the four principal areas described below.

#### a. Data Base Development

During the next five years, we will add to our climate data base and use the expanded base to prepare space-acquired data sets, develop a data management system, establish standards to ensure compatibility and continuity between observations taken with different instruments, and satisfy the data needs of user agencies. Seasat, Nimbus-7, Tiros-N, and the Earth Radiation Budget Satellite (ERBS) will be the principal suppliers of data. ERBS, to be launched in 1982, will be the first satellite dedicated primarily to climate studies.

#### b. Special Studies

We will make several studies related to physical processes that are believed to influence climate significantly. One study will consist of theoretical, laboratory, and field investigations of the chemistry and radiative properties of natural (volcanic) and man-made aerosol particles, and assessment of the effect of those particles on regional and global climate. Another study will seek to develop an understanding of the role played by clouds in the radiation balance between the Sun, Earth, and space. It will include development of theory as well as remote and in situ observation of the properties of clouds and other radiation-balance components. A third special study will address the interactions between the oceans and the air masses in contact with them, and related oceanic processes. It will use theory and experiments to determine the relationships between the storage and transport of heat in the oceans and the physical features and properties that can be observed on the oceans' surface; namely, currents, temperature, and waves. Its objective will be to add to our understanding of the heat, hydrological, and momentum cycles of Earth's climate system and of the global balance of such critical gases as carbon dioxide.

Other special studies will address cryosphere-climate processes, the hydrological influences of soil moisture on climate, evapotranspiration and vegetation, and the physical mechanisms by which changes on the Sun affect Earth's weather and climate.

#### c. Modeling and Analysis

We will conduct climate modeling and analysis activities to support development of observing systems and to provide effective techniques for interpreting and using space-acquired data to analyze and predict climate. ERBS will be a major source of data for this activity, as will the solar-monitoring Active Cavity Radiometer planned for flight on the Shuttle starting in 1981.

#### d. Definition of Observing Instruments

NASA's climate program relies to the greatest possible extent on existing and planned research and on operational satellites to establish the requirements for observational data. Over the next five years, we will concentrate on defining and developing instruments to satisfy the highest priority unsatisfied requirements, and on proposing which of them should be flown in the late 1980s.

## **7. National and International Relationships**

NASA's Environmental Observation program spans a very broad range of activities that involve national and international cooperation and that are essential to a sound and comprehensive applications program. Those activities range from adjunct relationships to formal commitments.

At the national level, all elements of our Environmental Observation program include major involvement with NOAA, EPA, and DOD. For example, we design, fabricate, launch, and check out operational weather satellite systems for NOAA and participate in the NOAA-managed National Climate Program established by the National Climate Act.

Internationally, our cooperative activities range from participation in programs conducted directly with one or more other countries to participation in United Nations programs. Examples are our major contribution to the Global Atmospheric Research Program (GARP) and the GARP Global Weather Experiment; our participation, through our upper atmospheric research program, in the multiyear, multinational study, "The Middle Atmosphere Program"; and a Tripartite Agreement with France and Great Britain on ozone monitoring.

## **8. New Initiatives**

### **a. Operational Support Initiatives**

#### **(1) National Oceanic Satellite System (NOSS)**

NOSS is the keystone of our planned oceanic program. We are undertaking it jointly with NOAA and DOD. Considering that Seasat was a demonstration of proof of concept, we are developing NOSS as a demonstration of limited operating capability, but with the expectation that it will lead to a fully operational ocean-observing system. NOSS will be a 2-satellite system that will observe the oceans for as long as 5 years. Data it collects will serve both the operational and the research communities. NOSS will build on Seasat's contributions. It will measure sea surface wind, temperature, wave height, chlorophyll, and turbidity; the location and concentration of sea ice; and ocean currents. It will also provide otherwise unavailable data for climate studies.

#### **(2) Advanced Operational Meteorological System**

This next-generation global weather satellite system will be an operational follow-on to the current Tiros and Geostationary Orbit Environmental Satellite systems. It will consist of low-Earth-orbit and geostationary satellites that are compatible with the Shuttle and that will ensure continued NOAA meteorological operations by providing data on winds, clouds, surface temperatures, Earth's radiation budget, and severe storms.

### **b. Research Initiatives**

#### **(1) Upper Atmosphere Research Satellites (UARS)**

The objective of UARS is to enhance our understanding of the stratosphere and the mesosphere, and our ability to assess potential threats to the upper atmosphere and its ozone layer. UARS will consist of two major activities. The first will be a comprehensive global study of the composition,

energetics, dynamics, and couplings of the upper atmosphere. The second will be to measure simultaneously the upper atmosphere's chemical species, temperature, winds, emissions, and solar inputs for two and a half years with two overlapping 18-month satellite missions.

(2) Ice and Climate Experiment (ICEX)

ICEX will be a polar orbit mission to measure Earth's cryosphere (sea-and sheet-ice, glacier, and snow cover) in order to understand its dynamics and its role in climate, and to assist marine and polar operations. The cryosphere is the largest single variable affecting Earth's climate. Instruments on Landsat, Nimbus, and Seasat have demonstrated their ability to make long-term observations of polar regions through persistent clouds and throughout the long polar night. We are currently determining the best method for implementing ICEX, with emphasis on use of NOSS equipped with modified or added instruments.

(3) Topography Experiment (TOPEX)

TOPEX's objectives are to increase understanding of the global circulation of the oceans and to demonstrate the usefulness of remotely sensed data in studying the oceans by means of continuous observation of ocean currents as depicted by changes in sea level. Those observations are as critical for understanding the oceans as wind measurements are for understanding the atmosphere. Both GEOS-3 and Seasat have demonstrated a limited ability to observe ocean currents from space. We believe that we can increase that ability considerably. With our ability to calculate orbits accurately, we can employ an altimeter in a relatively high, stable orbit to provide data that can be combined with the improved data on Earth's gravity that Gravsat will provide, and with data on the interior of the ocean that the acoustic tomography program being conducted by ONR and NSF will provide, to routinely produce observations of currents over large ocean areas. We plan to conduct, during 1980, a concept definition study of TOPEX to establish its requirements, justification, and system options. Present science priorities indicate that TOPEX should be a satellite carrying an altimetry payload and occupying an orbit with a relatively low (about 65°) inclination.

(4) Instrument Definition and Development

The objective of this activity will be to define and develop a selection of instruments able to support an aggressive program for measurement of both atmospheric and oceanic processes. The following instruments are the principal ones whose development we plan to initiate during the next five years:

(a) Light Intensification, Detection, and Ranging (LIDAR)

Currently, we are studying the concept of a multiuser, evolutionary, atmospheric LIDAR system for use on the Shuttle. Active remote sensing of the atmosphere has advantages such as high spatial resolution, an ability to provide diurnal measurements of chemical species in the troposphere, high specificity, and simplified data analysis. The objectives of this project will be to capitalize on those advantages in spaceborne studies and to study atmospheric transport models and the global flow of water vapor and pollutants in the troposphere and lower stratosphere.

**(b) Crogonic Limb-Scanning Interferometer and Radiometer (CLIR)**

We are also studying the concept of a multiuser CLIR system for use on the Shuttle. CLIR's objective will be to extend the mixing ratios of spaceborne infrared-emission sensors to  $10^{-12}$  to  $10^{-9}$  by volume and their altitude range to 60 to 120 kilometers in order to increase their ability to make sensitive measurements of atmospheric emissions.

**(c) Oceanic Processes Instruments**

We will define three instruments for use on the Shuttle, starting in 1984, to measure oceanic processes. The first is the Dual Antenna Altimeter, which we expect to use on TOPEX. The second, the Dual Frequency Scatterometer, will be an improved Seasat instrument for measuring surface wind fields. The third, the Ocean Synthetic Aperture Radar, will be an improved Seasat L-band synthetic aperture radar that will provide digital data and will increase resolution and swath width.

**(d) Atmospheric Processes Instruments**

We will start to define six atmospheric instruments and to develop one, the Advanced Meteorological Temperature Sounder, whose feasibility and operational readiness we have demonstrated in ground tests. We expect this passive infrared sensor to reduce the temperature profile error and improve the vertical resolution of temperature measurements in the troposphere by a factor of two. The six instruments to be defined are LIDAR temperature and pressure sounders, an instrument for mapping lightning, and instruments for measuring precipitation, wind, and solar spectral irradiance. They will either provide new measurement capabilities (e.g., the Lightning Mapper) or improve current capabilities (e.g., the Solar Spectral Irradiance Instrument). They are vital to progressive observation and forecasting programs. The Solar Spectral Irradiance Instrument has been identified for flight on Shuttle sortie missions. Flight arrangements for the remaining instruments are yet to be determined.

**(e) Space Principal Investigator (PI) Instruments**

Of the proposals received in response to its Announcement of Opportunity for PI instruments, the UARS program selected eleven, both foreign and domestic, that included both reflights of Spacelab 1 and Spacelab 2 instruments and definition of new instruments.

**9. Schedule and Funding**

Table 10 shows the phasing of the Environmental Observation program and Figures 20 and 21 show the program's funding requirements.

The phasing shown for the program is not optimal. The level of the 1981 budget and the expected level of the budgets for the remaining four years of this plan will not permit an optimum schedule. We have, therefore, had to assign priorities, with resulting delay in some programs, the UARS for example, and deferral of other programs to years beyond the period of this plan. The plan does, however, support our operational commitments, provide a minimum funding level for development and flight of payloads on Spacelab, and permit initiation of three high-priority missions.

TABLE 10 -- ENVIRONMENTAL OBSERVATION PROGRAM SCHEDULE

PROGRAM	RESPON- SIBLE FIELD CENTER *	PROGRAM PHASE		ADDITIONAL IMPORTANT INFORMATION
		INITIA- TION	LAUNCH COMPLE- TION	
Nimbus-7 Stratospheric Aerosol and Gas Experiment Earth Radiation Budget Satellite-A Measurement of Air Pollution from Shuttle Halogen Occultation Experiment Atmospheric Trace Molecules Observed by Spectroscopy Atmospheric Cloud Physics Laboratory National Oceanic Satellite System (NOSS) Upper Atmosphere Research Satellites (UARS) Ice and Climate Experiment (ICEX) Topography Experiment (TOPEX) Light Intensification, Detection, and Ranging (LIDAR) Advanced Operational Meteorological System Ocean Research Mission	GSFC	Ongoing	1978	1982
	GSFC	Ongoing	1979	1981
	GSFC	Ongoing	1982	1984
	LaRC	Ongoing	1980	1981
	LaRC	Ongoing	1982	1983
	JPL	Ongoing	1982	1983
	MSFC	Ongoing	1982	1983
	GSFC	1981	1986	--
	GSFC	1982	1985	--
	GSFC	1982	1986	--
	**	1983	1986	--
	LaRC	1983	1988	--
	GSFC	1984	1988	--
	**	1985	1989	--
				Shuttle experiment Shuttle experiment Shuttle experiment Shuttle facility Second launch 1987 Second launch 1986 Shuttle instrument Low-Earth-orbit and geosynchronous orbit satellites

\* GSFC = Goddard Space Flight Center

JPL = Jet Propulsion Laboratory

LaRC = Langley Research Center

MSFC = Marshall Space Flight Center

\*\* To be determined

**FIGURE 20.**  
ENVIRONMENTAL OBSERVATION CURRENT PROGRAM FUNDING

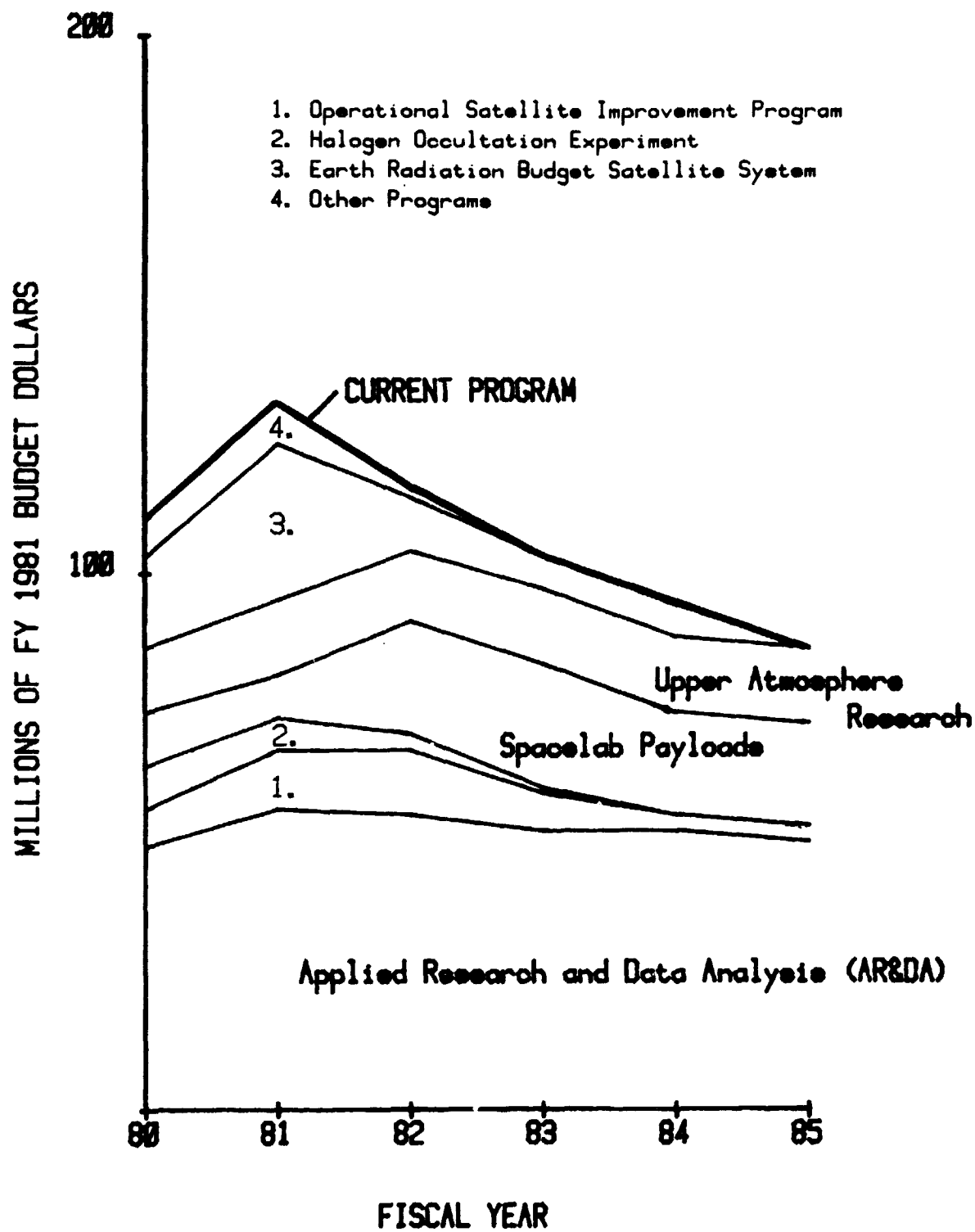
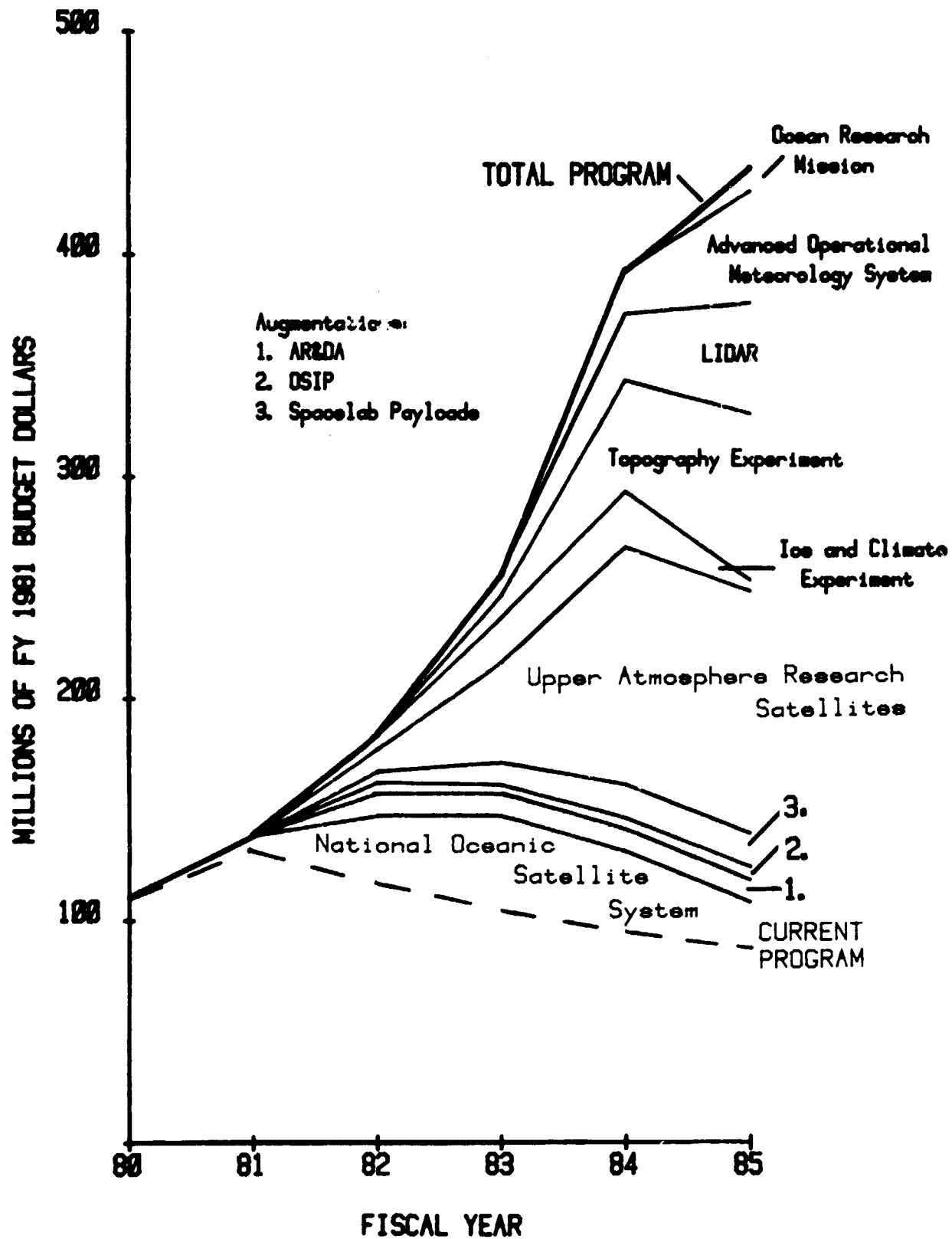


FIGURE 21  
ENVIRONMENTAL OBSERVATION TOTAL PROGRAM FUNDING



## **D. Earth Observation: Resources**

### **1. Goals and Objectives**

The goals of the Resource Observation program are to develop capabilities for applying space observations and space techniques and to develop enabling technology in order to help meet national and global needs for improved management of agricultural, range-land, forest, water, and land resources; to improve the effectiveness of exploration for mineral and energy resources through a better understanding of continental and global geology; and to increase understanding of the dynamic characteristics of the solid Earth and its crust, including crustal deformation and tectonic plate motion and stability.

The objectives for the program during the 1981-1985 period are:

- o Improved ability to forecast production of major agricultural commodities in primary producing areas
- o Improved ability to provide early warning of quantitative changes affecting production of major agricultural commodities
- o Improved ability to identify, discriminate, and inventory range land and major types of forests
- o Improved accuracy of land use classification and ability to detect, monitor, and model changes in land use
- o Improved ability to monitor and forecast water supply and demand
- o Improved ability to map geologic surface materials and configurations to aid in exploration for and assessment of mineral and hydrocarbon deposits
- o Techniques for analyzing conventional and remote sensing data in parallel with field data to better understand surface and subsurface geology on a continental and global scale
- o Development and demonstration of systems for precise measurement of tectonic plate motion and crustal deformation
- o Development of a standard reference model for Earth dynamics
- o Development of new concepts for acquiring improved remotely sensed data and field data, and for the extraction and timely availability of information for users
- o Maximization of the probability of maintaining continuity of Landsat data for the benefit of all users.

### **2. Program Strategy**

The philosophy underlying the entire Resource Observation program is to conduct all applications of remote sensing in conjunction with the user community -- federal agencies; state, regional, and local governments; private industry; and the scientific community. We will seek the maximum possible degree of user participation in every program activity from planning an application to transfer of that application to the user or users. We will implement this strategy by

developing the scientific understanding required for applying remote sensing and other space techniques to the study of static and dynamic characteristics of Earth's land surface and internal structure, and by working with potential users to identify important problems of national and global scope associated with resources and related scientific matters and to develop and demonstrate the application of space observations and techniques in solving the problems.

### 3. Current Capabilities

Our current resource-observation capabilities have evolved from multispectral visible and infrared remote sensing systems, satellite scalar and vector magnetometry, satellite tracking, laser ranging, and radio-frequency Very Long Baseline Interferometer (VLBI) measuring systems. Those sensors and measurement techniques have demonstrated their ability to contribute uniquely in many Earth-related applications; for example:

- o Production forecasting techniques for wheat
- o Identification of areas in which crops display stress
- o Ability to inventory land cover associated with Levels I and II land use maps
- o Location, classification, and mensuration of major types of forests
- o Identification of shoreline changes, salinity zones, and flood-plain boundaries
- o Identification of water impoundments greater than two acres in surface area
- o Determination of the extent of snow cover and inclusion of the resulting data in water supply models
- o Mapping of global magnetic anomalies to an accuracy of  $2 \times 10^{-8}$  Tesla and with a resolution of 300 kilometers at Earth's surface
- o Mapping of global gravitational anomalies to an accuracy of  $10^{-2} \text{ cm/sec}^2$  and with a resolution of 500 kilometers at Earth's surface
- o Identification of several major kinds of igneous and sedimentary rocks and of alterations that iron-rich compositions cause in them
- o Delineation of geochemical alteration associated with uranium mineralization in arid environments
- o Identification of structural discontinuities in Earth's crust in both vegetated and barren regions
- o Direct measurement of the relative motion of tectonic plates
- o Measurement of external gravitational influences on solid-Earth tides, polar motion, and variation in rate of rotation.

#### 4. Major Program Elements

##### a. Renewable Resources (Agriculture, Forestry, Land Use, and Water Resources)

This major element of the Resource Observation program will emphasize research, development, and testing techniques to satisfy the information needs that are identified by the U.S. Department of Agriculture (USDA) and that are defined in the program, Agriculture and Resource Inventory Surveys through Aerospace Remote Sensing (AGRISTARS). AGRISTARS will also benefit, to a lesser degree, the agribusiness, forestry, range, land use, and water resources communities. However, the unique needs of those communities will require some additional research and development.

##### (1) AGRISTARS

AGRISTARS is a 6-year cooperative program led by USDA and being conducted by USDA, NASA, NOAA, the Department of the Interior, and the Agency for International Development. It is a balanced program of research, development, and testing that addresses the management of domestic resources and provides information on the global condition and production of commodities. It uses remote sensing techniques to obtain information on commodities important to world trade such as wheat, soybeans, corn, barley, sorghum, sunflowers, and rice; to improve early warning of changes caused by episodic events such as droughts, floods, and infestations; and to assess the effects of those episodic events on yields. The space data required by this program will be acquired by the Multispectral Scanner on Landsat and the higher resolution Thematic Mapper on Landsats D and D'.

We will initiate research in 1980 to provide a capability to qualitatively assess 19 crop-region combinations for 6 major commodities in this country and 7 foreign countries. We will subsequently expand that capability to provide techniques required for use of satellite data to provide assessments of events affecting production quantity. We will also observe 12 crop-region combinations in this country and 6 foreign countries to improve the precision of acreage estimates in this country and to provide an operational capability for making improved forecasts of production in the foreign countries. Throughout the program, the USDA-led User Evaluation Group will assess the value that USDA line offices might be able to derive from the techniques, procedures, and products developed by the program.

Hydrologists and climatologists, as well as agriculturists, need to know the moisture content of the soil. Consequently, we are formulating a research and development program to develop means for measuring soil moisture by use of remote sensing. That program will assess the value of visible, infrared, and active and passive microwave techniques for that measuring task.

##### (2) Land Use

Our land-use activities during the next five years will emphasize use of existing and planned data acquisition abilities to improve our predictive and management models, change our monitoring capabilities, and establish common data bases to facilitate timely, periodic, and objective updating of land-use categories. Our secondary emphasis will be on improving our system for classifying land cover in coastal zone, urban, and suburban regions. Because the most dynamic changes in land use are occurring in those regions, repetitive remote sensing appears promising.

### (3) Water Resources

We will focus our research related to water resources on incorporating remotely sensed data into hydrologic modeling and -- because of the importance of moisture both to agriculture and to hydrologic phenomena -- on improving our ability to monitor soil and snow moisture. We will expand our demonstrations with users to include derivation of detailed hydrologic measurements from the higher-resolution data we acquire with the Thematic Mapper. We will base our development of systems on the requirements for data on water resources and hydrology generated by the World Meteorological Organization in 1976.

#### b. Non-Renewable Resources

The goals of this second major element of the Resource Observation program are to improve our understanding of the structure and evolution of Earth's crust and to develop an ability to determine the composition and configuration of the materials in that crust. To meet those goals, this program element will develop better methods to perform reconnaissance and exploration surveys by use of remote sensing techniques, and to advance the state of the art in resource exploration and assessment by synthesizing information from ground-based, aerial, and orbital measurements.

During the next five years, we will focus on development of remote sensing techniques to detect compositional and structural variations within crustal materials. We will test methods for assessing the utility of different techniques for discriminating between types of rocks and for mapping their structures in a variety of environments. We will augment the Landsat base of synoptic data with stereoscopic, thermal infrared, microwave, and geomagnetic measurements from space. We will emphasize combined analysis of remotely sensed electromagnetic data and field data to investigate 3-dimensional variations in crustal structure and composition. Essential activities include development of:

- o An ability to detect and discriminate bare soils and rocks on the basis of their chemical composition and mineralogy as indicated by their spectroradiometric properties.
- o An ability to determine soil and rock composition in vegetated regions by understanding the relationships between the distribution, morphology, and composition of plant species and the composition of the rock material underlying them.
- o An understanding of how structural lineaments are expressed at the surface and of the manner in which crustal fractures influence mineralization processes. Structural lineaments are observable in imagery acquired in the visible, thermal infrared, and microwave spectral regions. Ground-based studies will help determine the relationship of those lineaments to deep-seated crustal fracturing and deformation. The Large Format Camera, to be flown on the Shuttle in 1981, will provide stereoscopic, panchromatic imagery with a resolution of approximately 10 meters. We will also acquire data on surface topography with the Shuttle Imaging Radar (SIR-A), a modified Seasat L-band Synthetic Aperture Radar (SAR) scheduled to fly on the Shuttle in 1980, 1983, and 1984. We will derive the design characteristics for an

advanced SAR for topographic studies from the results provided by SIR-A and aircraft flights in order to initiate development of the Earth Resources Synthetic Aperture Radar (ERSAR).

- o An improved understanding of the relationship between anomalies in gravitational and magnetic field potentials and the structure of the crust in regions of known mineralization. Early in the 5-year period of this plan, we will use available gravity data and data from Magsat to determine variations in field potentials over areas containing mineral deposits. Then we will initiate development of the Tethered Magnetometer and use data acquired by Magsat-B and Gravsat to improve our ability to identify the variations in crustal density, thickness, temperatures, and composition that give rise to anomalies in those field potentials.
- o Models of crustal structure and evolution based on space-acquired data. Space systems will provide repetitive synoptic global measurements of Earth's surface that we can use to compare the geological settings of known mineral deposits comprehensively and systematically.

#### c. Geodynamics

We have formulated our geodynamics program to be the focal point for broad-based international research on Earth's rotational dynamics, tectonophysics, and the structure and composition of the solid Earth. The program's objectives are to identify causative relationships for changes in Earth's polar motion and rotation rate; to produce, over a period of 10 to 20 years, models of the contemporary motion (rate and direction) of the major tectonic plates, and to understand the forces driving the plates; to model the accumulation of crustal strain in seismically active areas in order to understand the mechanisms associated with earthquakes; and to study Earth's internal dynamics. NASA also will initiate a geodynamics research program leading to the formulation of an integrated, comprehensive model of global dynamic processes.

We are developing and executing our program in concert with other federal agencies (U.S. Geological Survey (USGS), NSF, NOAA, and Defense Mapping Agency (DMA)) that have responsibilities for geodynamics research, and in cooperation with other countries and international entities. NASA will assume primary responsibility for developing precise measurement technology and space systems. When appropriate, NASA will transfer those technologies and systems to operational agencies such as the National Geodetic Survey (NGS).

We plan to conduct, during the next five years, activities in the specific geodynamics areas described below.

##### (1) Polar Motion and Earth Rotation

Under NOAA's Polaris program, NASA and NOAA will develop and demonstrate the use of long base line, microwave, interferometric methods to improve the accuracy and resolution of measurements of polar motion and Earth rotation. The objective is an operational NOAA system in 1983. NASA will also continue measurements with Lageos and retroreflectors on the Moon; and NASA and NOAA will be the principal U.S. participants in Project MERIT (Monitoring of Earth Rotation and Intercomparison of Techniques) sponsored by the International

Astronomical Union. Project MERIT will make a global comparison of VLBI, laser ranging, and conventional optical systems as a prerequisite to adoption of a new international system in the mid 1980s.

(2) Tectonic Plate Motion

We will monitor the rate and direction of motion of the major plates, starting in 1980 and 1981 with measurements of the relative motions of the North American, Pacific, and Australian plates. During the 1981-1983 period, we will add the Eurasian plate, using measuring facilities in Germany, Sweden, and Japan. By 1985, we will incorporate the African, South American, and several minor plates into the global system.

(3) Intraplate Deformation

In a joint program with Canada, we will study the internal deformation of the North American plate to seek clues to the causes of intraplate earthquakes such as the Madrid, Missouri, 1812 earthquake. Starting in 1980, we will also study the deformation of the Pacific and Australian plates. If those studies find evidence of appreciable deformation, long-term (10- to 20-year) measurements may be required before the processes and their geophysical significance are understood.

(4) Regional Crustal Deformation

We will initiate in 1980 measurements of regional deformations in the western United States. NOAA and NGS will assume responsibility for those measurements in 1983. We will extend our regional studies to Central and South America and to the Caribbean in 1981, and to other seismically active areas, such as Alaska, in 1982. After 1983, depending on progress with international arrangements and assuming that NOAA and NGS have assumed full responsibility for measurements in this country, we will initiate detailed regional studies in South America, New Zealand, Europe, and Asia. We will continue those regional measurements through at least 1986 on the basis of two to three visits per year to selected locations. To support this series of measurement programs, NASA will improve the mobility and performance of VLBI systems, demonstrate highly mobile laser systems, and procure two mobile VLBI systems and one Transportable Laser Ranging Station.

(5) Local Crustal Deformation

Our objective is to monitor strain within 20 to 100 kilometers of active faults to an accuracy of  $10^{-7}$  kilometers. Because such local measurements must be made frequently and in concentrated areas, current techniques for making them are inadequate. Candidate new methods include use of radio interferometers with the Global Positioning System (GPS) in a project called Satellite Emission Radio Interferometric Earth Surveying (SERIES), and use of a spaceborne laser ranging to retroreflectors on the ground (Spaceborne Geodynamics Ranging System, or SGRS). NOAA, NASA, DMA, and USGS will jointly develop and demonstrate several methods using GPS, with NASA developing an interferometric method using transmissions from GPS as radio sources analogous to VLBI's use of radio stars as sources. In 1982, a joint interagency program to test GPS receivers will be conducted, the preferred GPS method will be selected, and a decision will be made as to whether local-deformation monitoring should be done with GPS or with SGRS.

## (6) Geopotential Fields

Studies in geodynamics and non-renewable resources require modeling of Earth's gravity and magnetic fields; studies of oceanic processes require gravity field models from which a precise ocean geoid can be established; and studies of secular variations, core-mantle interactions, and the historical decay and reversal of Earth's magnetic field require annual, global measurements of that field. Current gravity-field models use data acquired by ground-based systems, satellite tracking data, and satellite altimetry measurements. However, the accuracy and resolution of those data and measurements must increase if we are to verify the existence of mantle convection and assess its role in plate motion; to provide the geoidal accuracies needed for ocean studies; and to study Earth processes associated with sedimentary basins, shield areas, and orogenic belts. A proposed initiative, Earth Gravity Field Survey Mission (Gravsat-A), which would use satellite-to-satellite tracking, could provide most of the required increase in accuracy and resolution. Further increases will require other devices, such as a gravity gradiometer. We will develop the technology for the gradiometer and have the gradiometer available for follow-on gravity missions in the late 1980s.

### d. Landsat

We will launch Landsat-D and Landsat-D' in late 1981 and early 1982, respectively, to replace Landsat-2 and Landsat-3. In addition to providing continuity of Multispectral Scanner data through the mid-1980s, Landsat-D and Landsat-D' will provide Thematic Mapper data. Those data will have broader spectral coverage by virtue of their inclusion of the mid and thermal infrared frequencies, and will have greater spectral and spatial resolution. Data from both of the sensing systems will support the research activities of the AGRISTARS, Renewable Resources, and Non-Renewable Resources program elements.

### e. Operational Land Observing System

In November 1979, the Administration committed this country to an operational system for sensing the characteristics of Earth's land areas from space and assigned management responsibility for that program to NOAA. NASA will be responsible for research and development for the operational system, for development and demonstration of the system's protoflight sensor, and for subsequent sensor and spacecraft improvements. NOAA will operate the system and will be responsible for procuring additional space systems. We currently are working with NOAA to develop a plan for the transition from our research and development oriented remote sensing program to the NOAA operational system.

## 5. New Initiatives

### a. Renewable Resources

#### (1) Fundamental Research Program

We will augment our funding for AR&DA to initiate this program in 1982. This program will significantly broaden and strengthen the scientific base for applied research and development programs directed at the use of aerospace remote sensing in monitoring Earth's renewable resources. The

general areas to be emphasized include characterization of sensed radiations and atmospheric effects, pattern recognition and image analysis, electro-optical radiation, data compression techniques, and information use and evaluation.

(2) Multispectral Linear Array

Adequate forecasting and early warning for commodities require an increase in the frequency of coverage in primary producing areas and an ability to determine and monitor soil moisture. We can provide the required increase in temporal coverage without adding satellite systems either by incorporating an off-nadir viewing capability in the next generation of multispectral sensors or by increasing their field of view. We plan to initiate development of that next-generation sensor, the Multispectral Linear Array, in 1982 and to deploy it in the mid 1980s. It eventually will replace both the Multispectral Scanner and the Thematic Mapper. It will be based on the technology of multilinear arrays and will have arrays covering the spectral range from 0.4 to 2.5 micrometers at bandwidths as small as 20 nanometers.

(3) Soil Moisture Research and Assessment Mission

With regard to soil moisture, our research has shown that passive and active microwave techniques can determine moisture levels in upper soil layers, but that further research is needed on methods for determining which frequencies best indicate the level of soil moisture in the root zone. We are also investigating the use of microwave techniques to measure snow-pack properties. We plan to initiate development of a Soil Moisture Research and Assessment Mission in 1983, for launch in 1986.

b. Non-Renewable Resources

Our plan for developing a capability for sensing non-renewable resources remotely from space starts with laboratory and field investigations under our AR&DA program; progresses to fabrication of a sensor and validation of its concept in an aircraft flight, also under our AR&DA program; and ends with an orbital experiment on either Spacelab or a free flyer.

(1) AR&DA Augmentation

Our plan includes augmentation of our AR&DA funding during the 1982-1984 period to:

- o Expand research in the reflectance properties of surface soils
- o Support flight testing of a broad-band, 0.4- to 2.5-micrometer, reflectance imager in aircraft
- o Initiate research in thermal infrared radiation
- o Investigate the thermal emittance characteristics of surface soils
- o Develop a multiband thermal scanner for use on aircraft
- o Initiate basic studies of Earth's crust
- o Investigate the dielectric properties of materials in Earth's crust and study those properties under realistic conditions

- o Investigate geobotanical phenomena
- o Improve techniques for reducing SAR digital data
- o Improve data interpretation techniques.

(2) Spacelab Instruments

To prove the concepts for the techniques developed under the AR&DA activities listed above and to demonstrate their utility, we will develop for flight on Spacelab a broad-band reflectance imager, a multiband thermal imager, a variable depression angle antenna for SIR-A, and a dual frequency multipolarization SAR.

(3) Tethered Magnetometer

Instruments to measure magnetic fluxes from altitudes of 100 to 200 kilometers would be a valuable resource, but those altitudes are inaccessible to aircraft and long-life spacecraft. The Tethered Magnetometer, scheduled for development in 1984, will provide that capability. It will consist of a satellite-mounted magnetometer that will be deployed into Earth's upper atmosphere by a tethering cable from the Shuttle's cargo bay. The cable will be stabilized by the radial gradient of Earth's gravity field. The Office of Space Transportation Systems is developing the tethering system.

c. Geodynamics

(1) Gravsat

Gravsat is a planned 1982 new initiative. It will make global measurements of Earth's gravity field to an accuracy of several milligal ( $\text{cm/sec}^2 \times 10^{-3}$ ) and a resolution of 200 kilometers or better to support studies of ocean currents and circulation, crustal anomalies, and forces driving Earth's tectonic plates. Gravsat will be a satellite in low (160-km) orbit tracked by another satellite in low Earth orbit. The satellite-to-satellite tracking concept has been demonstrated by the Apollo-Soyuz Test Project, Nimbus-6, and GEOS-3 in conjunction with the Advanced Technology Satellite.

(2) Magsat-B

We will initiate development of Magsat-B in 1984 to obtain repetitive measurements of Earth's magnetic field and thereby investigate, over a 5-year period, the field's variations in intensity and direction. Data from Magsat-B will supplement data acquired by Magsat-A. Magsat-B will be an Explorer-class satellite to be launched into a low polar orbit in 1986. Its principal instrument will be a scalar magnetometer, and it will make a series of 3- to 6-month surveys. After each survey, onboard propulsion will raise it to a storage orbit.

(3) Satellite Emission Radio Interferometric Earth Surveying (SERIES) or Spaceborne Geodynamics Ranging System (SGRS)

Studies over the past several years have examined the feasibility of both of these methods for measuring local deformation of Earth's crust. We will

develop and test a prototype SERIES system in 1980, procure field units in 1981, and use those field units in a joint agency comparison test in 1982.

SGRS would require only a few days of operation to measure relative locations with a precision of  $\pm 1$  centimeter for a network covering up to a million square kilometers. It could monitor crustal movements in many areas of the world and could detect ground motions before and after large earthquakes in near real time.

In 1982, we will select the more appropriate system for development and could initiate its development in 1984.

#### (4) Spacelab Payloads

We plan to initiate in 1982 development of several tests and demonstrations to be conducted aboard Spacelab. One consists of tests of the 3-axis, superconducting Gravity Gradiometer currently under development. Another is demonstration of global time transfer at an accuracy of one nanosecond or better using a hydrogen maser. That demonstration is planned as a cooperative effort with the U.S. Naval Observatory and the National Bureau of Standards.

#### d. Multidisciplinary Systems

During the 1981-1985 period, we will develop several systems, each of which will be able to provide data for several applications disciplines. The two most important of those multidisciplinary systems are described below.

##### (1) Earth Resources Synthetic Aperture Radar (ERSAR)

We will continue our research on the use of active microwave systems for mineralogical and geological exploration and for monitoring vegetation. Our major new initiative for that activity will be a multidisciplinary facility, ERSAR, whose development we will start in 1985. ERSAR will fly on Spacelab and will use multiple frequencies, multiple polarizations, and multiple look angles to explore for mineral and petroleum resources and to monitor water and vegetation resources.

##### (2) Advanced Thermal Mapping Applications Satellite

Evidence indicates that a thermal infrared sensor in a near-noon orbit, rather than a more general system in a morning orbit, acquires the maximum amount of data on the thermal inertia of soil. Therefore, we will conduct research on narrow thermal spectral bands early in the 5-year period and will start development in 1983 of a specialized system, the Advanced Thermal Mapping Applications Satellite, for launch in 1988 to acquire data on soil thermal inertia for a variety of users. That satellite will be a follow-on to the Heat Capacity Mapping Mission and the Spacelab Multiband Thermal Imager, and will carry an instrument to collect narrow-band, high spatial resolution, thermal data.

#### e. Land Observing Systems

##### (1) Landsat Follow-On

To provide continuity of data in the time after Landsat-D and Landsat-D' cease to operate and before the Operational Land Observing System starts

operating, we will procure two additional spacecraft in the Landsat-D series, Landsat-D" and Landsat-D' ". They will build on Landsat-D and Landsat-D' technology and will incorporate the Thematic Mapper with the Multispectral Scanner. We plan to initiate their development in 1982 and to launch them in late 1984 and mid 1985, respectively.

## (2) Operational Land Observing System

We will initiate development of the protoflight for this system in 1982, with a possible launch date of 1987. An interagency group chaired by NOAA will determine the system's requirements and configuration. Our conceptual studies have indicated that the system should consist of three satellites, two in orbit and a spare on the ground. The system will build on technology from the Landsat series and will incorporate the Thematic Mapper and more advanced instruments such as the Multispectral Linear Array as they become available. The concept for this system also envisions retrieval of Landsat spacecraft; refurbishment of the spacecraft and their sensors, as appropriate; and their incorporation into the system.

## 6. Schedule and Funding

Table 11 shows the phasing of the Resource Observation program, Figure 22 illustrates how some of the initiatives contribute to satisfaction of the program's goals, and Figures 23 and 24 show the program's funding requirements.

## E. Materials Processing in Space

### 1. Program Strategy

Most materials are prepared from liquids or gases under conditions that allow gravity to cause uncontrolled fluid motions. The Materials Processing in Space program provides a unique set of capabilities and opportunities to study such effects and develop methods to achieve enhanced control over the processing variables. Ultimately, a deeper understanding of materials processing should permit development of innovative processing technology that will be more adaptive with regard to the forms of energy that are available and to environmental constraints, and that will be attractive from the viewpoint of cost. Our research on materials processes therefore involves multidisciplinary investigations that will result in an effective basis for using new environments, such as that of space, to better understand, control, and adapt the processes. From that basis, we will encourage commercial applications of materials processing technology. We will do so by involving the private sector at an early stage in the innovation cycle so as to enhance the transfer and adoption of new processes for public use. This approach requires close collaboration between the scientific communities in government, the universities, and industry.

### 2. Program Thrust

The most important feature of the program over the 5-year period of this plan will be the establishment of a research base that will include the use of ground facilities to perform various studies relevant to low-acceleration processing capabilities.

### 3. Program Content

The program currently consists of three major processing areas: crystal growth and solidification, containerless processing, and fluid and chemical

TABLE 11 -- RESOURCE OBSERVATION PROGRAM SCHEDULE

PROGRAM	RESPON- SIBLE FIELD CENTERS*	PROGRAM PHASE			ADDITIONAL IMPORTANT INFORMATION
		DEFINI- TION	INITIA- TION	LAUNCH	
Multispectral Linear Array	GSFC	Ongoing	1982	1985	Nominal 5-year operating life Choice between SGRS and use of Global Positioning System in 1982
Gravsat-A	GSFC	Ongoing	1982	1985	
Landsat-D"	GSFC	Ongoing	1982	1984	
Landsat-D'''	GSFC	Ongoing	1982	1985	
Operational Land Observing System	GSFC	Ongoing	1982	1987	
Soil Moisture Research and Assessment Mission	GSFC	Ongoing	1983	1986	
Magsat-B	GSFC	**	1984	1986	
Tethered Magnetometer	GSFC	**	1984	1987	
Spaceborne Geodynamics Ranging System (SGRS)	GSFC	Ongoing	1984	1987	
Advanced Thermal Mapping	GSFC	**	1984	1988	
Applications Satellite	**	Ongoing	1985	1989	
Earth Resources Synthetic Aperture Radar	**	Ongoing	1985	1989	
Spacelab Payloads:	JPL, JSC	**	1982	1984	
Multiband Thermal Imager	JPL, JSC	Completed	1982	1983	
Variable Depression Angle Antenna for SIR-A	JPL, JSC	Completed	1982	1983	
Gravity Gradiometer	MSFC	Ongoing	1982	1984	
Global Time Transfer Experiment	MSFC	Ongoing	1982	1984	
Broad-Band Reflectance Imager	**	1982	1983	1985	
Dual Frequency, Multipolariza- tion Synthetic Aperture Radar	**	Completed	1983	1984	

\* GSFC = Goddard Space Flight Center  
JPL = Jet Propulsion Laboratory

JSC = Johnson Space Center  
MSFC = Marshall Space Flight Center

\*\* To be determined

# FIGURE 22 — THRUSTS IN RESOURCE OBSERVATIONS

	EXPLORATORY RESEARCH	TECHNIQUE DEVELOPMENT	PILOT TESTS	LARGE-SCALE TESTS	OPERATIONAL USE
COMMODITY PRODUCTION FORECASTING*	AGRISTARS	AGRISTARS	AGRISTARS	AGRISTARS	OPERATIONAL LAND OBSERVING SYSTEM (NOAA)
EARLY WARNING AND CHANGE DETECTION*	AGRISTARS	LACIE AGRISTARS	LACIE AGRISTARS	AGRISTARS	OPERATIONAL LAND OBSERVING SYSTEM (NOAA)
LAND USE*					OPERATIONAL LAND OBSERVING SYSTEM (NOAA)
SOIL MOISTURE	AGRISTARS	AGRISTARS	SOIL MOISTURE RESEARCH AND ASSESSMENT MISSION		
SNOW MOISTURE					
WATER SUPPLY AND DEMAND*					OPERATIONAL LAND OBSERVING SYSTEM (NOAA)
GEOLOGIC MAPPING OF SUBSURFACE MATERIALS	GEOSATELLITE TEST	THERMAL IR MAPPER SMIRN	THERMAL IR MAPPER		
SUBSURFACE GEOLOGIC MAPPING		ERSAR SIR-A	ERSAR		
MAGNETIC FIELD MAPPING	MAGSAT		TETHERED MAGNETOMETER MAGSAT-B		MAGSAT
GRAVITATIONAL FIELD MAPPING	GRAVSAT		GRAVSAT GRAVITY GRADIOMETER		
POLAR MOTION				LEGEND	
CRUSTAL DEFORMATION MEASUREMENTS				COMPLETED APPROVED FY 1981-1985 PLAN	

NOTE: COMPLETED WORK FOR WHICH NO PROJECT IS IDENTIFIED IS APPLIED RESEARCH AND DATA ANALYSIS.  
\*LANDSAT IS BEING USED EXTENSIVELY IN THIS PROGRAM AREA.

CRUSTAL DYNAMICS PROGRAM  
INCLUDING VLBI AND  
LASER RANGING

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7 25 80

**FIGURE 23.**  
**RESOURCE OBSERVATION CURRENT PROGRAM FUNDING**

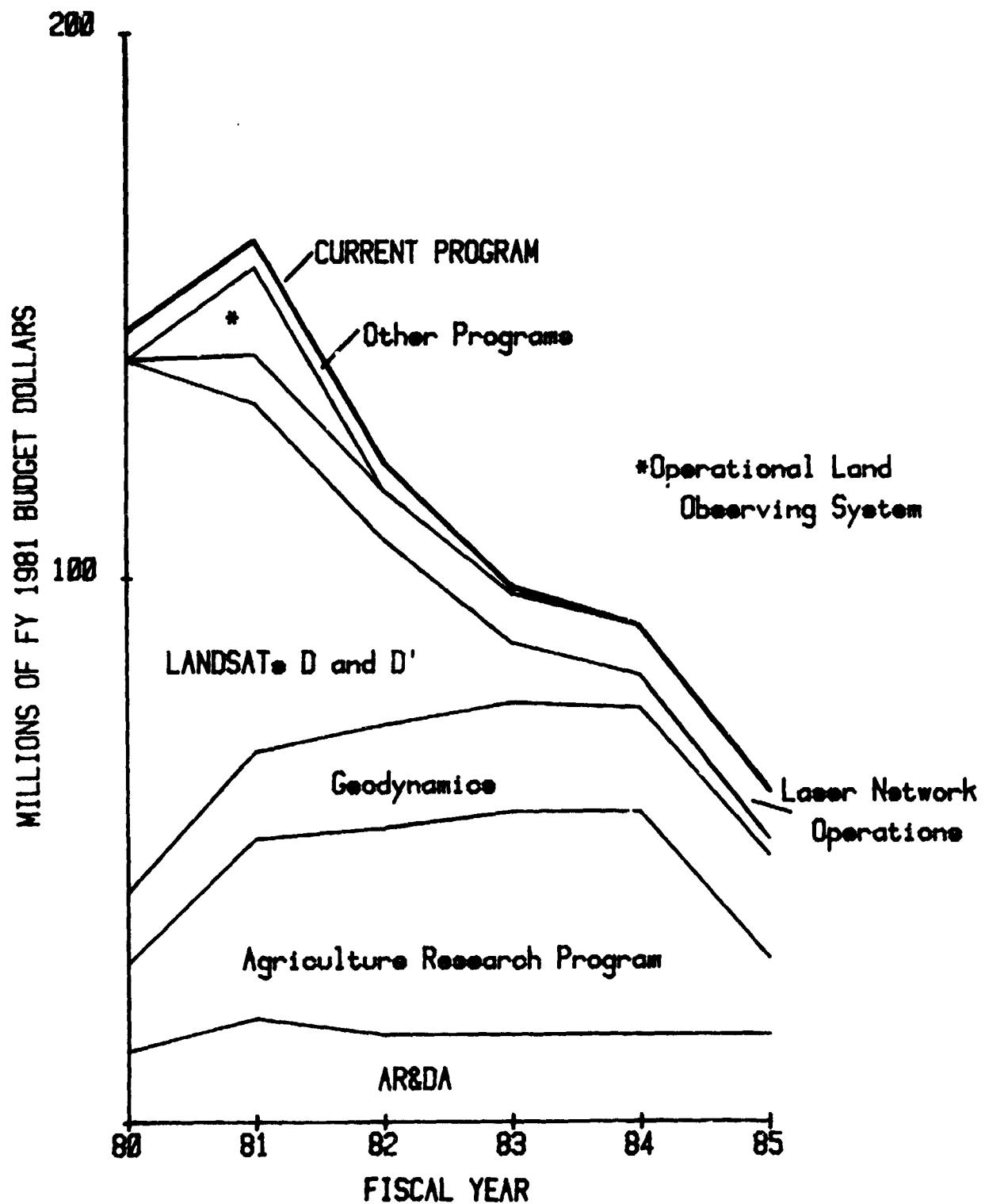
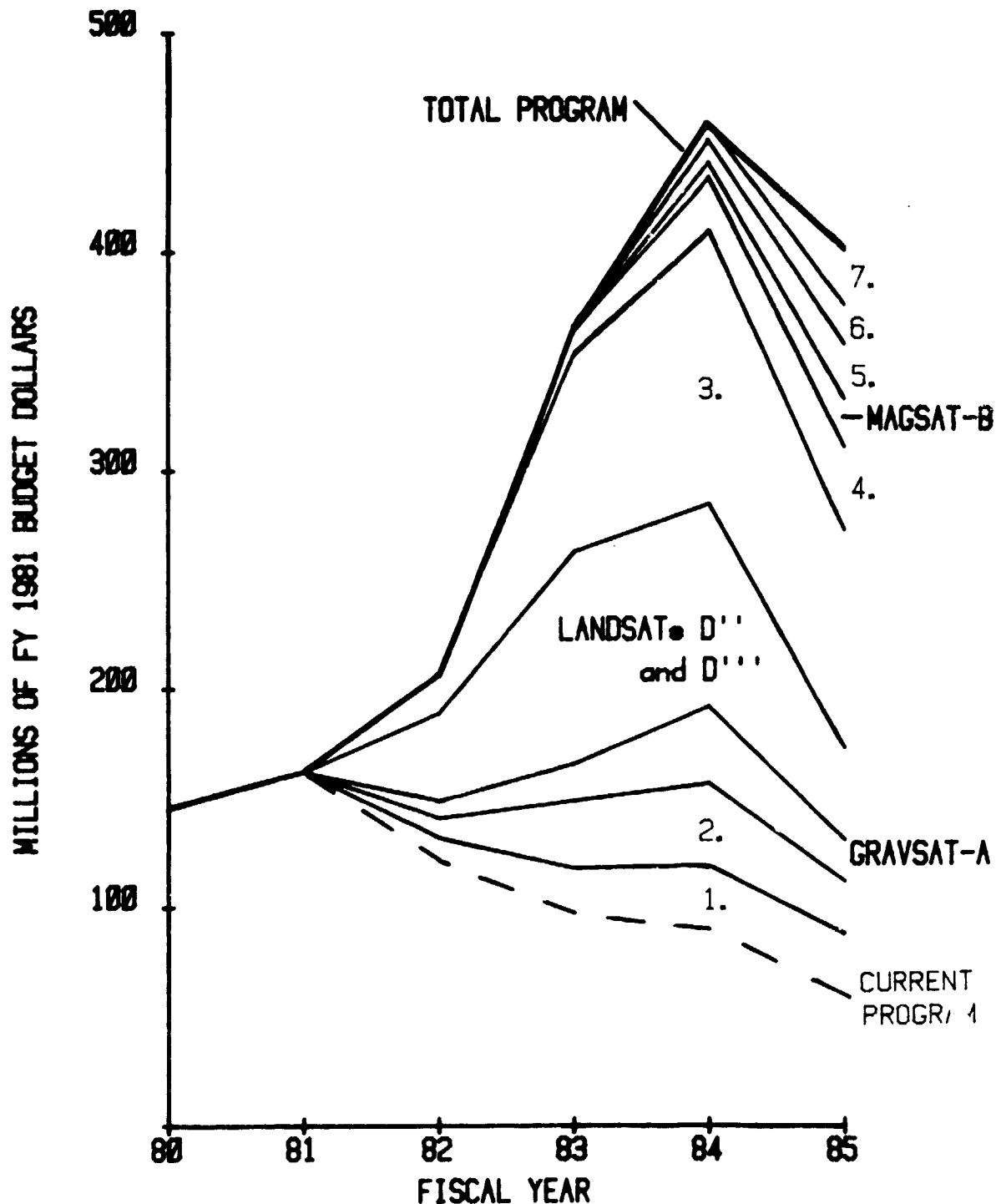


FIGURE 24.  
RESOURCE OBSERVATION TOTAL PROGRAM FUNDING



1. AR&DA Augmentation and Fundamental Research
2. Multispectral Linear Array
3. Operational Land Observing System-Protoflight
4. Soil Moisture Research and Assessment Mission

5. Spaceborne Geodynamics Ranging System
6. Advanced Thermal Mapping Applications Satellite
7. Earth Resources Synthetic Aperture Radar

processing. The origin of ground research in those areas is unsolicited proposals. Those proposals receive extensive peer review, and we will normally fund those that are accepted for as long a period as three years to encourage continuity and involvement with other program elements. The base which research provides enables us to define requirements for experimentation in space and to translate those requirements into the definitions of concepts that are essential for acquiring funds for the necessary space instruments and systems. That base also enables us to identify and support needed development of technology for those instruments and systems.

Selection of the experiments that will be funded will occur through an Announcement of Opportunity, which will be limited to the specific instruments and systems identified in the procedure described in the preceding paragraph. An important element of our program will be development of an intensive management scheme that will address the difficult problem of properly phasing the research, experimentation, technology development, acquisition of space hardware, and mission scheduling, integration, and operation. Effective interaction between those separate elements is vital to the success of the program and to ensure that maximum opportunities are made available for a series of flights at lowest possible cost. The comprehensive program-management concept that results will replace the more usual concept of optimizing individual missions in isolation.

#### a. Ground, Air, and Shuttle-Spacelab Research Capabilities

Over the period of this plan, we will develop a variety of capabilities to perform materials processing experiments under restricted low-gravity conditions. Those capabilities will include theoretical and experimental modeling and scaling, levitation facilities, drop tubes, and Keplerian-trajectory flights in aircraft and rockets. We expect those activities to identify the need for simple demonstrations and experiments that may be flown on a space available basis in the Shuttle-Spacelab system. We will combine sounding rockets and other devices into materials-experiment assemblies for flight on the Space Transportation System so that their interfaces with the Orbiter will be as simple as possible. Although these methods for accommodating experiments will be more restrictive than regularly scheduled flights on Spacelab would be, they will entail minimal expense while permitting both the scientific and the commercial communities to gain early experience with materials processing under simple conditions during experimentation periods as long as several days.

The components of the materials-experiment assemblies will, in aggregate, become a generic national laboratory for conducting materials investigations in space, and we will lease the resulting accommodations for experiments under favorable terms with regard to distribution of patent and proprietary data rights.

#### b. Materials Experiment Carrier

Advanced spaceflight capabilities will emphasize minimum cost. Current indications are that we can avoid considerable cost by using hardware initially configured for Shuttle-Spacelab pallets in conjunction with a power module operating in a free flying mode in low-Earth orbit. In collaboration with the Office of Space Transportation Systems, we are currently defining a structure, the Materials Experiment Carrier (MEC), which will serve as a platform for a variety of such hardware and will

provide the docking interface with the power module for the hardware. The MEC can be ready for use with a power module by about 1986.

#### c. Machine Intelligence and Robotics

Extensive use of machine intelligence and robotics to automate processes and make more effective use of in-orbit power, time, and energy could provide further savings in costs. We will examine possible applications of those techniques intensively over the 5-year period of this plan by means of definition studies and preliminary breadboard demonstrations.

#### d. Processing of Extraterrestrial Materials

Interest in the processing of extraterrestrial materials has been increasing because of the economics associated with the construction and development of large space systems and because of the possibility of future shortages of critical materials on Earth. Extrapolations of current technology indicate that space systems can be constructed with energy and materials resources available solely from extraterrestrial bodies. In fact, if those systems could then create products from extraterrestrial materials at an exponential growth rate, the economics would become extremely favorable. Exponentially growing systems are possible in principle, as we know from biological systems in Earth's biosphere. However, we currently know little about analogous systems adapted to the unique environment of space. In the 5-year period of this plan, we will seek new materials processing technologies that are adaptive both to the space environment and to the extrapolated capabilities of automated systems that incorporate teleoperator control and a degree of distributed intelligence that will offset expected delays in communications. We expect to organize, in collaboration with the Offices of Space Technology, Space Science, and Space Transportation Systems, a feasibility demonstration of those and other supporting technologies before the end of the planning period.

#### e. Materials Processing Center

To establish a more extensive research base and to provide a mechanism for close interaction with private industry, we have sponsored the formation of the Materials Processing Center at the Massachusetts Institute of Technology. The Center will carry out multidisciplinary studies of complex materials processes and problems of process automation and environmental adaptation from a systems perspective. We will encourage the Center to fund jointly with industry and other government agencies projects addressing materials processing research and technology of mutual interest.

#### f. Cooperative Activities

The Materials Processing in Space program conducts cooperative activities with government agencies, industry, and foreign countries. We have in process, and will strengthen, the following cooperative activities with other government agencies: studies with the National Bureau of Standards on basic materials processes, development with the Department of Energy of techniques for producing glass shells for use as inertial confinement fusion targets, development with the National Institutes of Health of bioprocessing methodology, and studies with the Defense Advanced Research Projects Agency of crystal growth and infrared detector materials.

We will continue our cooperative activities with industry through our Joint Endeavor program, under which an industrial firm may offer to develop and perform experiments relevant to materials processing in space on a no-exchange-of-funds basis. In this program, the Offices of Space Science and Space Transportation Operations will fund NASA's part of a limited number of that kind of experiments out of their existing resources for integration and operation of payloads. On that basis, the projects will serve as case studies of institutional problems associated with providing early stimulation to innovation in developing materials processing technology. We will coordinate the Joint Endeavor program closely with similar programs in the National Science Foundation's Division of Intergovernmental Science and Public Technology and with the Department of Commerce's Office of Cooperative Technology.

Russia, Germany, France, and Japan have substantial programs in materials processing in space, while member nations of the European Space Agency and Canada have smaller ones. The Russian program will most probably continue to use, throughout the period of this plan, the Salyut laboratory serviced by expendable launch vehicles. We will carry out cooperative ground and space research with the French, and we expect to share some missions with the Germans. The Japanese program is not yet at a mature stage; however, we will continue to discuss possible cooperative activities with the Japanese, mainly by the Announcement of Opportunity process.

#### 4. Schedule and Funding

Table 12 shows the phasing of the Materials Processing in Space program and Figure 25 shows the program's funding requirements.

#### F. Communications

NASA's plan for development of technology for satellite communications responds to a growing need for new and improved commercial services. The President's October 1978 Civil Space Policy removed former concerns about the direction the NASA program has taken since the 1973 phase down of new activity in NASA's research and development (R&D) flight program. In response to that policy, we will undertake carefully selected communications R&D, focusing on effective and efficient use of the limited radio spectrum and geosynchronous orbit resources.

Our communications program also encompasses data transmission and distribution and particular data processing operations that are common to the Environmental Observation and Resource Observation programs described earlier in this 5-year plan of the Office of Space and Terrestrial Applications (OSTA). Our emphasis is on employment of the most modern communications and data-system technology for OSTA missions, and on providing information from those activities to users for later application.

##### 1. Planning Assumptions

Projection of the demand for satellite communications indicates that saturation of the geosynchronous orbit and radio spectrum space in useful view of the United States is imminent. Users of point-to-point and broadcast services must compete for orbit and spectrum space. Consequently, we assume that imminent saturation coupled with a continuing growth in demand has created a requirement for new technology that will provide more effective use of the orbit and spectrum resources.

TABLE 12 -- MATERIALS PROCESSING IN SPACE PROGRAM SCHEDULE

PROGRAM	RESPON- SIBLE FIELD CENTERS*	PROGRAM PHASE			ADDITIONAL IMPORTANT INFORMATION
		DEFINI- TION	INITIA- TION	LAUNCH	
<u>SPACELAB PAYLOADS</u>					
Fluid Experiment System	MSFC	Completed	Ongoing	1982	1 additional launch in 1983, 2 in 1984, and 2 in 1985
Monodisperse Polymer Latex Reactor	MSFC	Completed	Ongoing	1982	2 additional launches in 1984 and 1 in 1985
Vapor Crystal Growth Furnace	MSFC	Completed	Ongoing	1982	1 additional launch each year 1983 through 1985
Solidification Experiments System	MSFC	Completed	Ongoing	1982	2 additional launches each year 1984 through 1987
Analytical Floating Zone Experiments System	MSFC	Ongoing	1981	1983	1 additional launch each year 1984 through 1988
Isoelectric Focusing System	MSFC	Ongoing	1982	1984	1 additional launch each year 1985 through 1988
Acoustic Containerless Experiments System	JPL	Ongoing	1983	1985	1 additional launch each year 1986 through 1988
Bioprocessing Experiments System	MSFC	1982	1984	1986	1 additional launch each year 1987 through 1989
<u>MATERIALS EXPERIMENT CARRIER PAYLOADS</u>					
Solidification Experiments System-II	MSFC	1981	1983	1985	1 additional launch each year 1986 through 1989
High Gradient Furnace	MSFC	1982	1983	1985	1 additional launch each year 1986 through 1989

\*JPL = Jet Propulsion Laboratory  
MSFC = Marshall Space Flight Center

TABLE 12 -- MATERIALS PROCESSING IN SPACE PROGRAM SCHEDULE (CONTINUED)

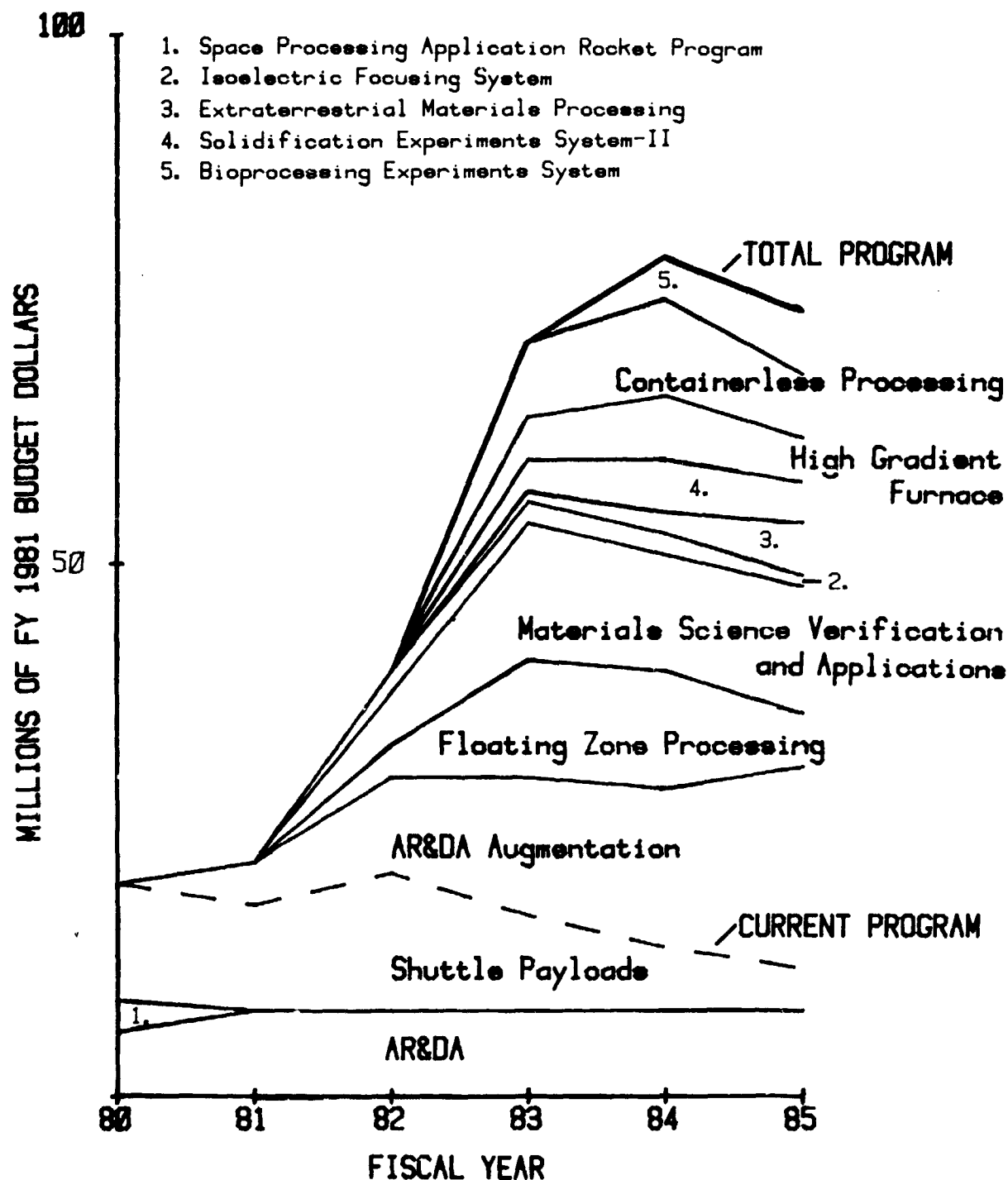
PROGRAM	RESPON- SIBLE FIELD CENTERS*	PROGRAM PHASE			ADDITIONAL IMPORTANT INFORMATION
		DEFINI- TION	INITIA- TION	LAUNCH	
<u>MATERIALS EXPERIMENT CARRIER PAYLOADS (CONTINUED)</u>					
Electromagnetic Containerless Processing	MSFC	1981	1983	1985	1 additional launch each year 1986 through 1989
Floating Zone Processing System	MSFC	1983	1983	1985	1 additional launch each year 1986 through 1989
Acoustic Containerless Processing System	MSFC	1982	1983	1985	1 additional launch each year 1986 through 1989
<u>MATERIALS SCIENCE VERIFICATION AND APPLICATIONS</u>					
Ground Facilities	MSFC	**	1982	**	
Aircraft and Sounding Rocket Experiments	MSFC	**	1982	***	
Precursor Spacelab Experiments	MSFC	**	1982	***	
Materials Experiment Assembly II	MSFC	**	1982	1984	1 additional launch in 1984, 2 in 1985, 1 in 1986, 2 in 1987, and 1 in 1988
Commercial Applications	MSFC	**	1982	1984	1 additional launch each year 1985 through 1987
<u>EXTRATERRESTRIAL MATERIALS PROCESSING</u>	JPL	**	1982	***	

\*JPL = Jet Propulsion Laboratory  
MSFC = Marshall Space Flight Center

\*\*Not applicable

\*\*\*To be determined

FIGURE 25.  
MATERIALS PROCESSING IN SPACE PROGRAM FUNDING



The K-band (30/20 GHz), allocated in 1971 to increase satellite communications capacity, has been inadequately explored and developed for use in the United States. Meanwhile, programs in foreign nations are proceeding with research and development of technology for that band. We foresee that foreign developments could reduce U.S. participation in a potential, large, worldwide market for K-band (30/20 GHz) systems.

As in former technology developments, NASA's R&D can supply the significant advance in the state of the art for the K-band (30/20 GHz) needed to satisfy the expanding demand for communications, thereby enabling U.S. industry to meet competitive requirements in the world market. We assume that, because the private sector's R&D must be based on near-term profit potentials, the necessary long-term, underlying R&D must be conducted by the government and that, once developed, the resulting technology will enable industry to confidently offer new and expanded services.

In the 1980s, applications programs will mature to the extent that successful use of their results will require very effective processing and use of data from many sources. It will be an era in which technical disciplines from agriculture to oceans and weather will be formulating large-scale models that will require timely access to and integration of data from a dozen or more sources. To satisfy those data access and integration needs efficiently and economically, we are planning to develop an Applications Data Service (ADS).

## 2. Program Strategy

The Communications program is based on a strategy to accomplish several objectives from a single fundamental technology base. While providing expanded use of the limited spectrum, we can improve on our current use of spacecraft antennas that have wide coverage patterns, and on separation of traffic among ground terminals by frequency channelization. High-performance, multibeam spacecraft antennas will allow the entire spectrum to be reused at separate ground locations communicating through a single satellite on different, non-interfering, antenna beams. A natural adjunct to that technology for adding flexibility to a communication system is "onboard switching"; i.e., flexible routing of traffic among beams. In addition, synchronized, time-switched access for traffic, if fast and efficient, is a strong advantage of that kind of technology.

We will pursue those combined antenna, switching, and access capabilities in parallel to provide insight into communications satellite systems that will be commercially desirable. Ground terminals working with those satellite systems could be simpler and more affordable than ground terminals that use more advanced, but complicated systems working with less capable space elements. Also, later implementation of the multibeam antenna technology at the broadcast-allocated Ku-band could result in development of broadcast satellites with recontourable beams, which could increase the much-needed isolation between national borders.

In the data-systems area, we will evolve the ADS as an integral part of existing and planned applications data systems, converging those systems into an integrated structure by applying common standards for data and data systems in developing network service for data transmission and integration. The standards will guide future programs to ensure that data and data products from next-generation systems such as the Upper Atmosphere Research Satellites and the Earth Radiation Budget Satellite can be readily exchanged and integrated.

The ADS network will furnish a common service to provide access to data and data catalogs, to provide required format conversions, and eventually to integrate the cross-correlative data sets required by multiple users. A user will be able to obtain aggregated data for any geographical region he wishes. He will be able, for instance, to request a Landsat image of New England and have the image overlaid with temperature and soil moisture data. The network, catalog, and data preparation services of the ADS should make it easier to determine what data are available and to provide those data in a more timely manner and a more usable form.

We will develop those and other technologies needed to meet the Nation's communications and data system needs late in this century by means of a modest, but broad, R&D program. We will conduct that program partly at two or three NASA field centers and principally (nominally about 90 percent of the total R&D effort) through those centers' contracting with industry in order to exploit specific industry expertise and to derive "leverage" from our internal R&D resources.

In the data systems program, we are conducting periodic workshops in which the user community and data system designers develop composite requirements and system configurations. We believe that the strategy of user involvement from the outset is an essential element in developing and guiding the program. An additional strategy is to phase the pilot tests of new concepts for data systems so that early tests in which users participate actively will point the way to incremental growth with a sound basis for each increment. Each step will allow user reactions, assessments, and recommendations to be fully considered.

### 3. Flight-Test Program

We have received strong recommendations that we conduct a flight-test program to prove the concept of the overall system and to provide lifetime testing in the space environment in which commercial systems are expected to operate. While that flight program will serve an important function and is technically and operationally feasible within this 5-year planning period, we will initiate it only when its need becomes clearly evident. We will define the program to protect our decision-to-proceed option for experimental flights, but flight testing of advanced hardware may evolve into new forms. Relationships developing among NASA, the Department of Defense, and the communications carrier and supplier industries show strong promise for effective conjunctions of effort in flight testing.

### 4. Program Guidance

Continuing guidance for all elements of the Communications program stems from established relationships among the program's staff, managers at NASA's field centers, and the Satellite Communications Applications Subcommittee of the Space and Terrestrial Applications Advisory Committee of the NASA Advisory Council (NAC). The NAC subcommittee consists of senior experts from industry and universities who review, discuss, and provide recommendations on the program's content and management and, in the process, give us needed insight into the communications activities of industry and the universities. Additional guidance for the data systems element of the program is derived from the workshops mentioned earlier and from additional advisory groups, principally the National Academy of Science's Committee on Data Management and Computation and the Subcommittee on Information Systems Technology of NAC's Space Systems and Technology Advisory Committee.

## 5. Interrelations with Other Program Offices

The Communications Division of the Office of Space and Terrestrial Applications (OSTA) maintains close coordination with other NASA program offices. It identifies and defines the basic long-term research and technology requirements for the advancement of in-orbit capability by performing advanced system studies (characterizations of potential communications-service systems, including conceptual designs and rough estimates), by closely observing industry cost and performance trends, by identifying legal and regulatory constraints on spectrum and orbit use, and by assessing user needs. As those research and technology requirements take form, OSTA and the Office of Aeronautics and Space Technology (OAST) make coordinated evaluations so that OAST's R&D to develop technology for hardware components can be included in the regular planning cycle. In preparation for each succeeding subsystem phase of applied R&D, OSTA keeps informed continuously on developmental progress to be able to ensure that subsystem- and system-level technologies and techniques will be available for use in industry initiatives, as needed.

When programs approach system-level activity, OSTA and OAST hold joint readiness reviews to provide for orderly transfer of responsibility from OAST to OSTA.

## 6. Goals and Objectives

The goal of the Communications program, including its data systems element, is to provide for:

- o U.S. technological leadership in satellite communications
- o Effective and efficient use of orbit and radio spectrum resources
- o Enhanced accessibility and utility of OSTA data sources and efficient, timely delivery of data products from OSTA missions.

The objectives of the program are to:

- o Develop the state of the art in multibeam antenna and onboard switching systems to provide significant increases in communications capacity
- o Conduct R&D applicable to the K-band (30/20 GHz) to ensure technological readiness for simulated system testing on the ground by 1984
- o Identify the services and users potentially best suited to the characteristics of the K-band (30/20 GHz); by 1982, plan allocations within that band as guidelines for industry and the regulating agencies
- o Initiate development of a narrow-band communications satellite system that will provide multiple voice and data communications and be compatible with terrestrial, ultra high frequency, cellular, radio-telephone systems
- o Through the phased establishment of an Applications Data Service (ADS), develop the state of the art in data access and in integrating data from observation of resources, the oceans, and the atmosphere.

## 7. Program Content

### a. Major Program

The principal effort in our planned communications R&D is the development of multibeam antennas for the K-band (30/20 GHz) and of onboard switching techniques essential to efficient use of orbit and radio spectrum resources.

### b. Continuing Activities

Several current activities of the Communications program and data systems element will continue into the planning period. One is to provide technical consultation support to other OSTA divisions, to other NASA elements, and to the Federal Communications Commission, the National Telecommunications and Information Administration (NTIA), and the Department of State. That support is related to orbit and radio-spectrum management, including studies of the propagation of signals and the sharing of radio frequencies.

Another continuing activity is to conduct search-and-rescue experiments to provide the Department of Transportation and the U.S. Air Force with an alert-and-locate capability. That capability will be based on the relaying by satellites of distress signals from emergency transmitters on ships and aircraft in trouble. Flight testing will occur in 1982.

The third continuing activity is to fabricate an L-band, adaptive, multibeam, phased-array antenna system and to complete testing on a nonadaptive, multibeam, Ku-band antenna system.

Three studies on the state of the art of, and potential needs for, various types of onboard switching comprise the fourth activity. Those studies are scheduled to end in 1981.

The fifth continuing activity is to provide technological support to NTIA. Two items of support are to assist the transfer to commercial communications services of experimenters previously using ATS-6 and CTS satellites, and to continue operating the ATS-1, -3, and -5 satellites, if their health continues to be adequate.

A sixth continuing activity is our ADS effort. In 1980, we will expand the preliminary studies of ADS requirements, concepts, and feasibility that we conducted in 1979. The results will support, in 1980, definition of initial standards and small pilot activities in the areas of oceans, atmospheres, and resources. Initial pilot systems that will become available in 1981 and 1982 will serve as test beds to demonstrate and evaluate alternative concepts for data access and integration. Common standards for interfaces and data formats will allow future interconnection of independent pilot systems into an "integrated" ADS pilot system. As ADS capabilities mature and are successfully demonstrated in the pilot activities, they will be incorporated into the OSTA data system.

We plan to initiate full-scale implementation of network, catalog, and access capabilities for the ADS in 1983 and to have them fully available in 1985. We will develop and demonstrate integration services and other advanced concepts from 1983 until the mid 1980s, at which time they will be mature enough for full-scale application.

As part of our continuing activity, we will assess several methods for acquiring ADS services, including leasing some or all of them from commercial concerns. That method would use commercially developed and financed systems. We will determine the probable availability of commercial services, the steps that would be required in arranging to use them, and the advantages and disadvantages of using them. To gain the interest of the commercial community, we plan to hold individual discussions with potential vendors and to give a general presentation on ADS to all interested vendors.

#### c. Advanced Studies

The Communications program for 1981 through 1985 contains the following advanced study areas:

- o Applied Research and Data Analysis. This area provides the core R&D that serves as the base for all our communications work. It will focus on development of technology for K-band (30/20 GHz) multibeam antennas and onboard switching, with associated activity in systems developments such as multiple access, comprehensive modulation, and advanced devices incorporating microwave integrated circuitry and other emerging basic advances.
- o Data Systems Research and Concepts Development. ADS and other advanced data-system concepts can be assessed only in the context of real missions. We will work with the other program offices to identify candidate missions, and will then conduct research, data-system analyses, and pilot tests to define appropriate capabilities to satisfy the needs of those missions.
- o Advanced Communications Applications. As the 30/20 GHz program moves into the implementation stage, we will evaluate and prioritize a wide variety of follow-on applications ranging from improved systems for educational television to advanced search-and-rescue concepts.

#### d. New Initiatives

The two major initiatives planned for the 1981 through 1985 period are described below.

##### (1) Wide-Band Program

As noted in the planning assumptions, development of the K-band (30/20 GHz) is essential to the growth of satellite communications. NASA's effort in this area consists of two activities, market analysis and system analysis. Two communications common carriers completed in 1979, under contract, market analyses that forecast the demand expected to develop in the 1980 to 2000 period; characterized the demand with regard to type of user, size of the demand, and demographics; projected service costs for both terrestrial and satellite systems; and forecast the satellite systems' share of the predicted market. Two satellite manufacturers completed, also in 1979 and under contract, systems analyses that assessed the technological state of the art, defined systems concepts, analyzed competitive alternatives, identified critical technology, and estimated system costs. In 1980, we will refine the results of those activities and clarify the critical system, technology, and policy issues.

The next steps in this initiative will be to establish conceptual designs; to develop critical technology, including that for multibeam spacecraft

antenna and onboard switching systems; and to determine the need for flight verification tests. Those activities will begin with project definition in 1981 and are expected to lead to program initiation in 1982.

## (2) Narrow-Band Program

The Wide-Band Program will satisfy some needs for additional communications capacity, but additional provisions will be necessary for many applications; for example, emergency and disaster communications and land-mobile voice communications. Hardware for UHF terrestrial terminals has already been developed to serve a large and growing market. Consequently, use of UHF frequencies via satellite promises the low costs required for service to low-volume users. It is likely that a portion of the UHF spectrum will soon be allocated for communications satellites to provide land-mobile communications. NASA's program will approach the development of those satellites by application of multibeam techniques to provide as much frequency reuse as practical in an anticipated spectrum allocation of only a few tens of megaHertz.

Developments at K-band (30/20 GHz) related to multibeam antennas and onboard switching will contribute to this program also. A key technology, that for the large antenna required for a UHF multibeam system, will be the first item for consideration. The remaining technology for the Narrow-Band Program is sufficiently close at hand that system development can be accomplished within that antenna's development and test period. The requirements for the antenna's components (reflector, lens, phased array, and combinations) and their characteristics are under study. As they are defined and the expected frequency allocations are made as a result of the 1979 World Administrative Radio Conference, the Communications Division will be able to accelerate its planning. We expect to initiate the Narrow-Band Program in 1984.

## 8. Funding

Table 13 shows the phasing of the Communications program and Figure 26 shows the program's funding requirements.

## G. Technology Transfer

During the past year, the Technology Transfer Division analyzed and assessed its aims and program. Using the guidance those activities provided, it decided to modify its approach to planning and to revamp its program. It has made considerable progress in doing so, with the results that are contained in the 1981-1985 plan described below. However, the planning approach and the planned program are still evolving, and are expected to continue doing so.

### 1. Goals and Objectives

The goal of the Technology Transfer program is to ensure that the application of NASA's technology provides the maximum possible benefits and that those benefits focus on high-priority national needs. To meet that goal, we will have to develop a comprehensive package of services that use NASA technologies and techniques to satisfy those needs.

The program's objectives are as follows:

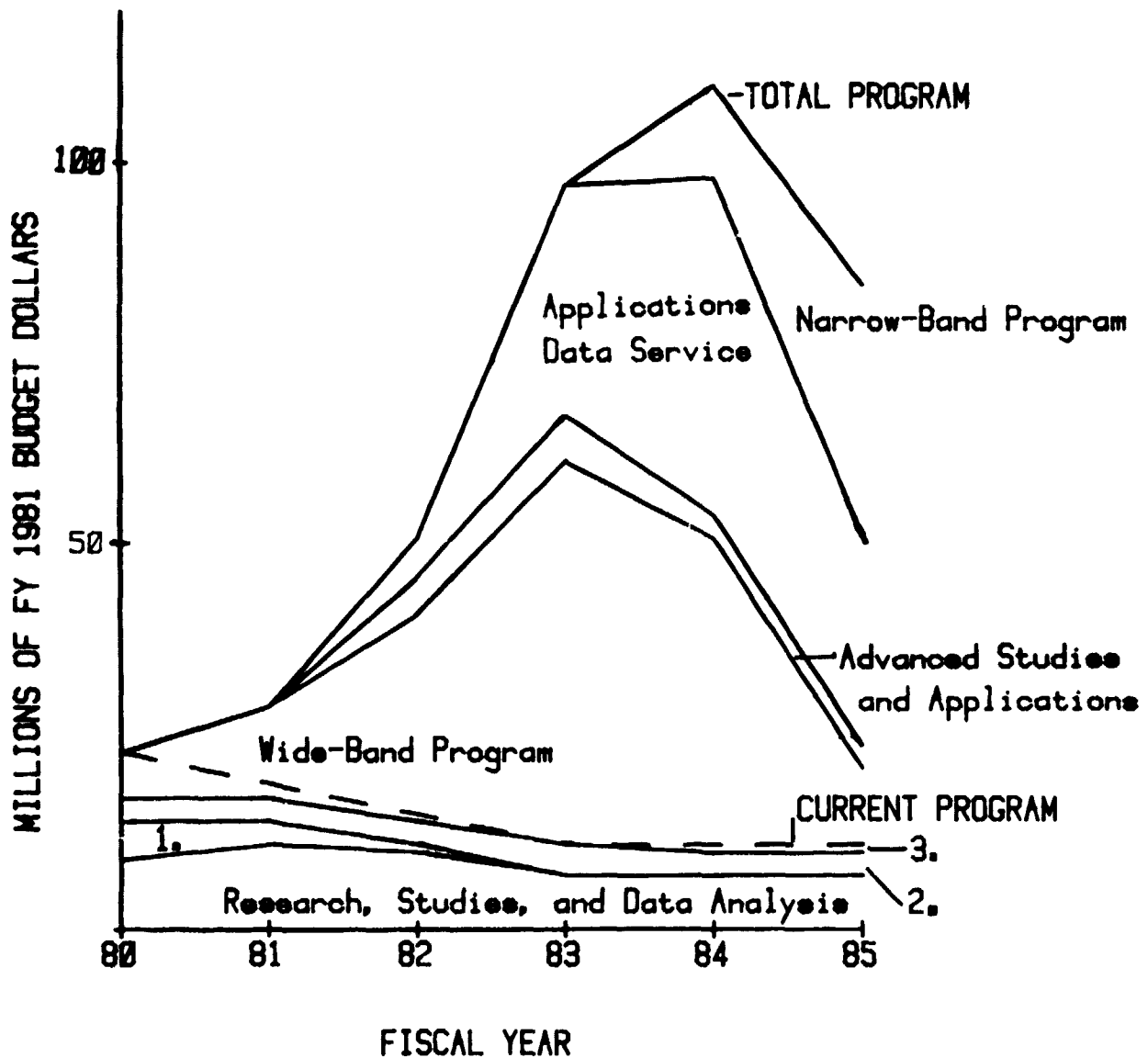
TABLE 13 -- COMMUNICATIONS PROGRAM SCHEDULE

PROGRAM	RESPON- SIBLE FIELD CENTERS *	PROGRAM PHASE			ADDITIONAL IMPORTANT INFORMATION
		DEFINI- TION	INITIA- TION	LAUNCH	
Wide-Band Program	LeRC	Ongoing	1982	1986	Phase II definition 1981 Developments at K-band (30/20 GHz) in wide-band program will contribute to this program
Narrow-Band Program	LeRC	Ongoing	1984	To be de- termined	
Applications Data Service	GSFC, JPL, JSC	Ongoing	1983	--	

\* GSFC = Goddard Space Flight Center  
 JPL = Jet Propulsion Laboratory  
 JSC = Johnson Space Center  
 LeRC = Lewis Research Center

FIGURE 26.  
COMMUNICATIONS PROGRAM FUNDING

1. Search and Rescue
2. Technical Consultation Program
3. Other Programs and Follow-On Operations



- o To combat the decrease in U.S. productivity by increasing the effectiveness of our Industrial Applications Centers and by encouraging private sector involvement in the use of remote sensing
- o To apply rehabilitation engineering to solve the problems of the aged and the handicapped
- o To explore the applicability of remote sensing and ground-based technology to environmental monitoring
- o To establish at least five new basic research centers at universities to support disciplines such as weather, climate, severe storms, oceanography, land resource management, agriculture, and communications
- o To explore the applicability of remote sensing to the detection of water color and the applicability of ground-based space technology to water quality
- o To improve agricultural information by determining the applicability of remote sensing to agricultural monitoring in the AgRISTARS program
- o To explore the applicability of applied technology to transportation systems and of remote sensing applications to transportation.

## 2. Program Strategy

Our strategy is to emphasize national priorities. It requires that we understand the role of other federal agencies, state and local governments, private industry, and the universities. It also requires that we understand technical needs, technology sources other than NASA, and NASA's capabilities; determine NASA's proper role and interest; and develop a strategy to determine the type and level of technical involvement appropriate for NASA. In using this strategy, we must consider the economic, social, and institutional effects of each technology application.

## 3. Program Organization

The Technology Transfer program is organized to perform the two functions described below.

### a. Space Applications Transfer

The activities under this function must be coordinated closely with the activities of the other divisions of the Office of Space and Terrestrial Applications. This function is concerned primarily with remote sensing technology and consists of the activities described in the next four paragraphs.

#### (1) User Requirements, Analysis, and Awareness

This activity consists of establishing and maintaining working relationships with user groups and change agents such as the National Governors Association, National Conference of State Legislatures, and Public Technology, Inc.; encouraging communications with potential users by preparing and distributing public information literature and by holding seminars and exhibits; and conducting analyses of user requirements and studies to evaluate technology.

(2) Applications Systems Verification and Transfer (ASVT)

ASVTs are multiyear projects that are funded jointly with public and private organizations. Their purposes are to adapt and transfer to groups outside NASA the remote sensing technologies that result from NASA's R&D, and to verify that the technologies can be applied to non-R&D problems in a cost-effective and meaningful way. The outcome of an ASVT project is a set of verified processes or techniques that the participating organization can use in its day-to-day operations.

(3) Regional Remote Sensing Applications

This activity seeks to help a broad base of users develop remote sensing capabilities. For administrative effectiveness, we have divided the country into three regions, with a NASA field center responsible for coordinating the work in each of the regions. Those centers are Ames Research center in California, Goddard Space Flight Center in Maryland, and the National Space Technology Laboratories in Mississippi. Their functions are to conduct demonstrations, to maintain liaison with users in their regions, to disseminate information, and to provide technical assistance and training to help users develop operational capabilities in the field of remote sensing.

(4) University Applications

This activity is our major instrument for producing the people trained in remote sensing that are critical to a successful, long-term, technology transfer program. Its principal mechanism for meeting that responsibility is grants to universities to sponsor research and education and to encourage them to provide public service by interacting with state and local governments to demonstrate practical benefits from the use of space technology.

b. Technology Utilization

This function is charged with the secondary application of aerospace technology. It consists of the three types of activities described below.

(1) Technology Dissemination

The foundation for this activity is a process we call New Technology Reporting. In accordance with Section 305(b) of the Space Act, we require each NASA contractor to report to us any technology it develops with NASA funds. We screen and process those reports and then disseminate them through our NASA Tech Briefs; our annual report, Spinoffs; other publications; and our dissemination centers. The dissemination centers include seven NASA-sponsored Industrial Applications Centers (IACs), two State Technology Assistance Centers (STACs), and the Computer Software Management and Information Center (COSMIC). The IACs and STACs provide computerized access to the NASA technical information data bank, while COSMIC specializes in computer programs.

(2) Technology Applications

This activity demonstrates the applicability of NASA technology to identified problems by building and testing prototype hardware. It is supported by Applications Teams consisting of experts from outside NASA. Each team specializes in an area such as manufacturing or bioengineering and

helps NASA identify technological problems in that area. Team members then work with staff members at NASA's field centers to locate existing appropriate technology, to develop possible solutions, and to help commercialize the final solution.

### (3) Program Evaluation Support

Our evaluative activities include qualitative and quantitative assessments of the impact that aerospace contributions make in selected fields of technology.

## 4. Program Content

Our funding level for 1981 precludes the undertaking of new activities that year. The thrusts that we will initiate in the remaining four years of this plan, 1982 through 1985, are described below.

### a. 1982 Thrusts

#### (1) Increased Productivity

We plan two thrusts to help increase U.S. productivity. The first one is to expand the contributions that our IACs can make. It will address the concern expressed by both the President and Congress about this nation's decreasing productivity. That concern is evident in several of their recent actions. Congress has proposed legislation related to industrial innovation, patent policy, and new programs aimed at infusing new technology into U.S. industry. It is studying intensively the institutional arrangements and the types of assistance the Government can provide, and is currently considering S.1250, a bill proposing Centers for Industrial Technology that would work with industry to provide a number of services stimulating R&D for generic technologies, educational services, and dissemination of technological information. The President has proposed a Center for the Utilization of Federal Technology located in the National Technical Information Service in the Department of Commerce. The Small Business Administration operates Small Business Development Centers that can affect national productivity, and the Department of Commerce operates Minority Business Development Centers serving the minority business community. Numerous other agencies operate commercialization centers.

One way in which NASA can contribute is to conduct a pilot program that will use the capabilities developed by other federal agencies in combination with our own capabilities to provide a broad base of services to industry. Our IACs can provide the technical information component to complement the financial, educational, and research services of other agencies. This pilot program will build on the experiences of three of our IACs that individually have various relationships with a limited number of agencies. Groups that may become involved include Congress, the Small Business Administration, the Economic Development Administration, and other federal offices.

The second productivity thrust will be aimed at stimulating productivity by increasing private sector involvement in remote sensing. We will develop strategies and will conduct projects to encourage the private sector to act both as a supplier of remote sensing services and as a user of remote sensing. We will emphasize significantly increased use of private suppliers of services as the technical arm of NASA's joint projects to transfer technology. We will design industry's participation to stimulate as much development as possible of non-NASA sources of technical assistance and to make the use of satellite-sensed data economical.

We will also work directly with architectural and engineering firms, agribusinesses, and other private industry organizations to encourage them to use remotely sensed data to increase their productivity. Market analyses will provide the basis for this activity.

## (2) Aid to Aged and Handicapped

Public Law 96-602 was enacted as a result of the 1977 White House Conference on Handicapped Individuals and several follow-up panel meetings in which NASA participated. That law amended the Rehabilitation Act of 1972 and created the National Institute for Handicapped Research (NIHR) within the Department of Education. It also established an Interagency Committee on Handicapped Research chaired by the Director, NIHR, and with representation from NASA. That committee's purpose is to coordinate policy, objectives, and priorities for all federal programs relating to research for the rehabilitation of handicapped individuals. NIHR is conducting joint projects with NASA and other agencies in areas of mutual interest involving rehabilitation, as well as research and development in rehabilitation engineering and the use of telecommunications systems, including satellite telecommunications systems, to meet the needs of handicapped individuals.

The aged constitute a continuously increasing fraction of the U.S. population, and estimates place the fraction of the population that is handicapped at about 20 percent. Approximately 3 percent of the population require rehabilitation engineering services and products. We have consulted agencies responsible for aid to the aged and handicapped to identify areas in which NASA could assist. The most promising areas include communication aids, living and movement aids, materials, diagnostics, and treatment.

NASA programs in voice communications, telecommunications, and intelligent systems are and will continue to contribute technology for communication aids. Our work in energy and controls and our systems analyses continue to point the way to improve transportation aids and housing. Ion beams designed for our low-thrust, high specific impulse, propulsion systems provide a means for making a new class of textured biocompatible materials. Micro-miniaturized image processing devices and multispectral analysis techniques developed for space applications will lead to new non-invasive diagnostic techniques. Labeling techniques based on low temperature magnetics, techniques for focusing high-frequency waves, ultrasonics, valves, and micro-miniaturization techniques developed in telemetry and rocket programs are all in use in the designing of new medical treatment techniques.

Several organizations that are involved in transferring technology to the aged and the handicapped are potential users of those NASA-developed techniques, procedures, and devices. They are NIHR; various organizations in the Department of Health and Human Services; National Institute of Arthritis, Metabolism and Digestive Disease; National Cancer Institute; National Eye Institute; Veterans Administration; National Science Foundation; Department of Housing and Urban Development; Library of Congress; and many organizations for the aged and handicapped such as the American Foundation for the Blind.

## (3) Environmental Monitoring

Concern at the national level about the quality of the environment has been at an all-time high the last few years. Some of the legislation reflecting that concern is the Coastal Zone Management Act of 1972, the

Surface Mining Control and Reclamation Act of 1977, and the Clean Air Act. In developing capabilities for monitoring the environment, we plan to use two approaches--sensing the environment remotely from space and applying space technology to ground-based activities related to monitoring the atmosphere.

Improvements in the Landsat series of spacecraft and expected advances in techniques for detecting changes will increase the utility of remote sensing systems. We plan to exploit that increase by thrusts in three areas:

- o Coastal Zone Management and Surface Mining. In cooperation with state and federal agencies, we will demonstrate the use of our improved abilities to detect changes in and to discriminate between kinds of vegetation and to monitor changes in coastal zones and the recovery of land that has been surface mined.
- o Air Quality. In 1982, we will begin an ASVT activity to verify our ability to monitor air quality from space. In 1983, we will start transitioning that activity to our Regional Remote Sensing Applications program.
- o Weather. As another ASVT activity, we will initiate cooperative projects with potential users to sense from space the tracks of severe storms; air pollution; the height, thickness, growth, and motion of clouds; and the temperature of land and sea surfaces.

Some of the existing space technology that may be applicable to ground-based monitoring of the environment are sensing, data recording, data management, and data packaging techniques for a wide range of environmental pollutants; techniques for the conversion of organic wastes to useful raw materials and fuels; multispectral analysis and image enhancement techniques related to environmental effects on vegetation; and techniques for monitoring toxic and radioactive materials. The two initial areas we plan to investigate for application of that technology are air quality and weather, especially severe storms. Organizations that may use the abilities we develop include the Environmental Protection Agency (EPA), state and local environmental agencies, local public weather services, and commercial weather services.

#### (4) Expansion of University Basic Research

This thrust will provide support to universities so that they can perform basic research related to national priorities and NASA technology. We plan to establish basic research centers at five or more universities. Candidate areas for their research are weather, climate, severe storms, oceanography, land resource management, agriculture, and communications.

##### b. 1983 Thrust: Water Quality Monitoring

As in our environmental monitoring thrusts, we plan to use the two approaches of sensing from space and applying space technology to ground-based monitoring. Several significant pieces of legislation identify the national concern for water quality and establish regulatory requirements that the states and local governments must enforce. They include the Federal Water Pollution Control Act, as amended by the Clean Water Act, and the Coastal Zone Management Act.

Remote Sensing of water quality is potentially applicable to the following:

- o Pollution from Non-Point Sources. Measurements from Landsat of changes in land use can provide critical inputs to hydrologic models and to the monitoring of changes in water color.
- o Lake Eutrophication. Landsat, the Coastal Zone Color Scanner (CZCS), and airborne scanners can consistently and efficiently rank the trophic status of lakes, monitor changes, and guide cleanup programs.
- o Measurement of River Basins and Wetlands. Landsat data can be used to establish land-cover base lines, delineate environmentally sensitive areas, monitor changes, and assess the results of the changes.

Landsats 1, 2, and 3 have demonstrated their ability to characterize factors that affect water quality, and Landsat-D's 30-meter resolution and wider spectral bands are expected to improve that ability substantially. The CZCS is specifically designed to improve Nimbus 7's ability to detect water color, which appears to be an indicator of water quality. The CZCS also has been proposed as an operational instrument for the National Oceanic Satellite System, which is scheduled for launch in 1985. However, we must conduct additional research before we will be able to assess our ability to monitor inland and coastal waters and to improve our ability to model the relationship of changes in land use to changes in water quality. We anticipate that the results of that research combined with expected improvements of in situ sensors could significantly improve the state of the art for monitoring water quality.

Potential users of the technology we develop include EPA, the National Oceanic and Atmospheric Administration, the Corps of Engineers, and State and local governments.

Existing space technology that may be applicable to ground-based monitoring of water quality includes that for automated monitoring of waste water and water treatment facilities. Our initial emphasis in applying that technology will be on identifying efficient and reliable methods for monitoring national water resources continuously and in near real time. Areas we will have to address are development of improved sensors; automated data collection, processing, and analysis; and a low cost, self sustaining, monitoring network suitable for use in regional monitoring systems. Potential users are EPA, the U.S. Department of Agriculture (USDA), the U.S. Geological Survey, state and local governments, and industrial and public institutions.

#### c. 1984 Thrusts

##### (1) Agricultural Monitoring

The national need for greater amounts of more accurate agricultural information is a continuing one, and remote sensing from space can contribute significantly to satisfying that need. We plan to establish cooperative programs with non-USDA users of agricultural information to transfer to them the technology emerging from NASA's AgRISTARS program and related agriculture research and development projects in such areas as the following:

- o **Agricultural Land Productivity.** We will transfer to non-USDA users techniques for forecasting crop production developed under the AgRI-STARS program.
- o **Irrigated Lands Mangement.** We will transfer to users technology currently emerging from pilot tests.
- o **Identification of Prime Agricultural Lands.** We will transfer to state agencies both the improved data from Landsat-D and interpretation techniques that will enable them to identify prime agricultural land and uses for it.
- o **Evaluation of Range Resources.** We will transfer to federal, state, and private users improved techniques for evaluating the potential of range land to produce biomass and support grazing.
- o **Soil Erosion Susceptibility.** We will demonstrate the incorporation of Landsat data into geo-based soil erosion models as part of our Regional Remote Sensing Applications program.

Potential users are state agricultural agencies, agri-businesses such as fertilizer manufacturers and large ranching operations, state extension services, and range management and ranching organizations such as the National Cattleman's Association.

## (2) Deep Oceans Technology Development

Evidence shows that this nation's commitment to the oceans is not commensurate with that of other nations and that we are not fully exploring and exploiting the potential benefits to be derived from the seas. Several studies recently published both within and outside the federal government have expressed the need for reassessment of national priorities in marine research and the use of ocean resources. In October 1978, for example, the Department of Commerce released a document, U.S. Ocean Policy in the 1970's: Status and Issues, that states: "The Nation's stake in the ocean is increasing in economic terms, and it is likely to continue to expand. The central issue is whether the governmental apparatus and the private sector as they now exist are sufficient for the amount, extent, and intensity of present and prospective uses of the ocean. A parallel issue also exists: What is the proper role of the Federal government vis-a-vis the states and private sector in meeting the ocean needs of the Nation?"

A June 16, 1978, report by the General Accounting Office details several perceived deficiencies in the Nation's management of its oceanographic assets. Several Congressional committees have expressed their interest and concern by requesting the Office of Technology Assessment to prepare by July 1980 a study of future needs for research in ocean technology.

NASA's current activities consist of applying aerospace-derived concepts and methodologies to provide technological assistance to federal agencies and oceanographic institutions in three areas: fixed platform systems for long-term sea-floor operations, a mobile platform system for surveying and exploring the deep oceans, and sea-floor remote sensing that applies advanced image processing techniques to acoustic imaging of the ocean floor. We recently initiated an internal review of our deep ocean activities, with the

objectives of collecting information needed to formulate the Agency's position regarding its appropriate role in 1980 and beyond in developing and demonstrating deep ocean technology in support of national ocean activities.

Organizations presently involved in the three areas of ocean research listed in the preceding paragraph include the Office of Naval Research, the National Oceanic and Atmospheric Administration, the British Institute for Oceanographic Sciences, the Woods Hole Oceanographic Institution, Scripps Institute of Oceanography, and several universities. We plan to develop cooperative programs with additional federal agencies, such as EPA, the Department of Energy, and the National Science Foundation, as appropriate. As systems for surveying, exploring, and exploiting the deep oceans are demonstrated for operation use, the private sector -- both users and service industries -- will become involved.

d. 1985 Thrust: Transportation Applications

During the 5-year period of this plan, we will apply our aerospace-derived technology to two aspects of the Nation's current programs to improve mass transportation systems and to limit the effects of transportation on our environment. First, we will investigate the following three areas for their possible application to energy efficient, reliable, mass transportation systems for urban areas:

- o Improvement in the performance of urban mass transit systems, particularly with regard to their reliability and to development of maintenance techniques that will provide high in-service rates
- o Passenger safety, keyed to fire suppression through the use of non-toxic, low flammability materials
- o Reduction in system costs through use of aerospace engineering techniques such as configuration management and the effective application of performance specifications.

Some of the areas of existing aerospace technology that could be applied to transportation systems are reliability and quality assurance, configuration management systems, coatings for corrosion resistance and control, energy-efficient motors, motor control systems, energy storage and recovery systems, lightning detection and protection systems, systems analysis, improved metallic alloys, and lightweight, non-metallic structures. The ultimate users of the resulting transportation systems will be the riding public, who will be seeking transportation alternatives to the private automobile.

Our second activity in connection with this transportation thrust will relate to use of remotely sensed data in determining the effects of transportation on the environment. Typical applications relate to urban and metropolitan land use, urban census estimates, and transportation-corridor impact assessments. We will transfer to federal, state, and local governments and to private sector users the urban and metropolitan transportation technologies we will have developed based on the improved spatial, spectral, and radiometric data provided by the Landsat-D Thematic Mapper. The expected users of those technologies are city planners; federal, state, and local transportation and census agencies; and architectural and engineering firms in the private sector.

## 5. Interrelations with Other NASA Programs

The Technology Transfer Division has strong ties with other divisions within OSTA, with the program offices in the Headquarters, and with NASA's field centers. Those ties are vital to the Division's continued effectiveness. For example, the Division transfers to users the remote sensing applications developed in the Environmental Observation and Resource Observation divisions of OSTA and, in return, provides those divisions with information on user needs. Also, the Division's Technology Utilization Office must have intimate knowledge of the complete spectrum of NASA's technological developments to be able to match user needs with potential secondary applications of those developments.

## 6. Funding

Figures 27 and 28 show the Technology Transfer program's funding requirements.

FIGURE 27.  
TECHNOLOGY TRANSFER PROGRAM FUNDING  
SPACE APPLICATIONS

1. ASVT Weather Data Demonstration
2. Environmental Monitoring

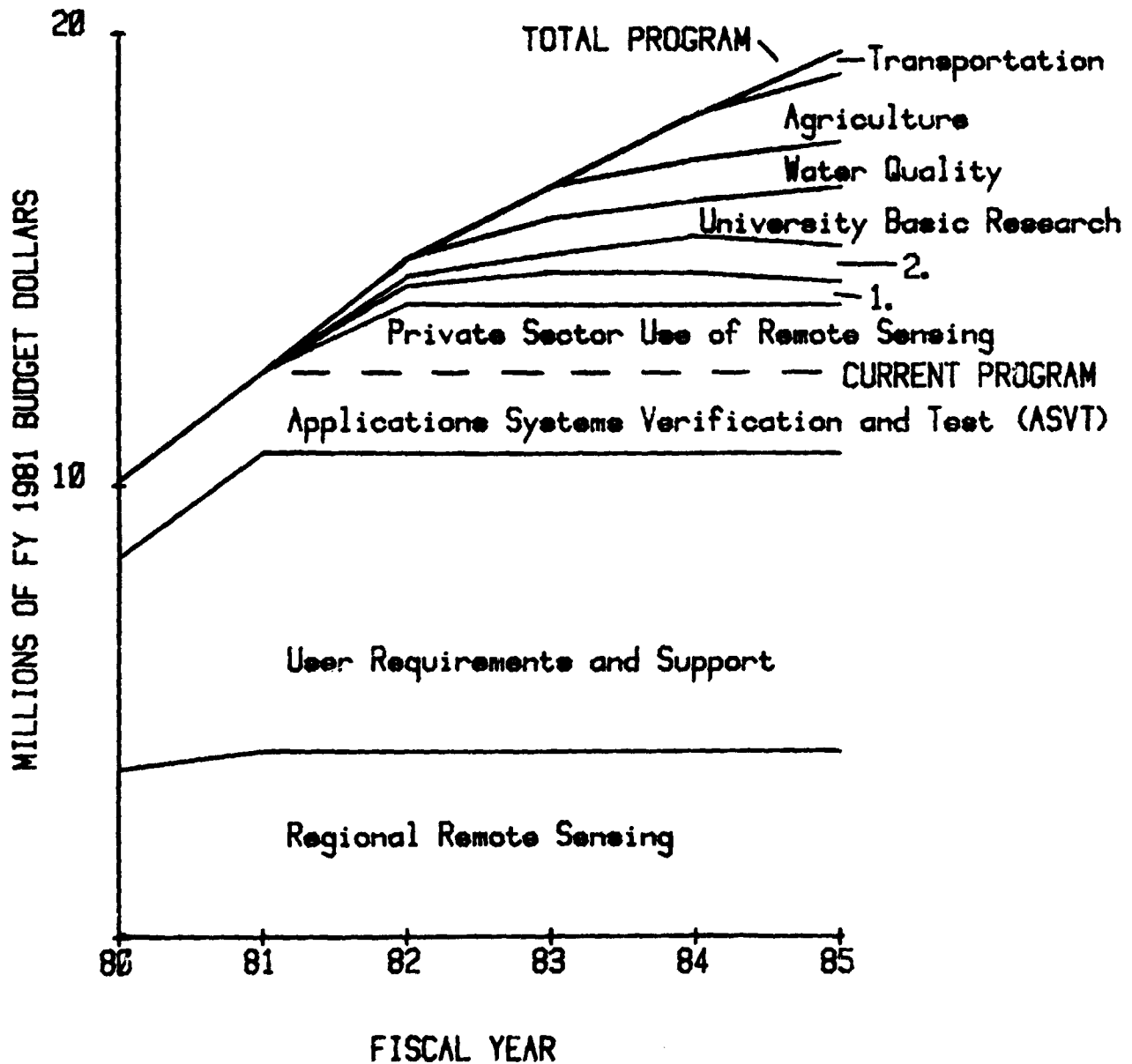
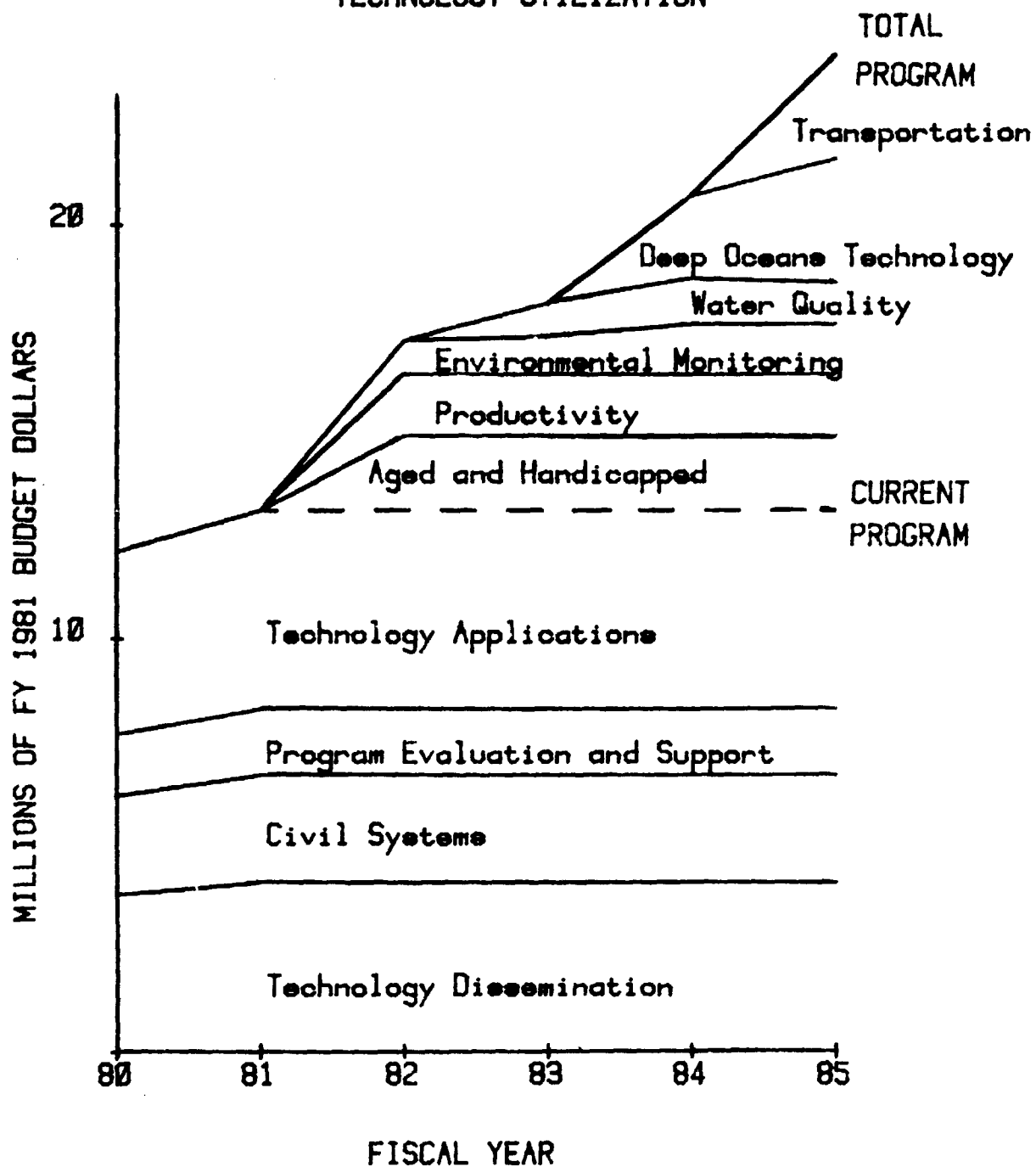


FIGURE 28.  
TECHNOLOGY TRANSFER PROGRAM FUNDING  
TECHNOLOGY UTILIZATION



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## VI. ENERGY TECHNOLOGY PROGRAM

NASA is authorized to conduct programs in support of the Nation's energy research and development needs by the Energy Reorganization Act of 1974, the Department of Energy (DOE) Organization Act of 1977, and the National Aeronautics and Space Act of 1958, as amended. The DOE-NASA Memorandum of Understanding dated March 21, 1978, describes the general conditions under which DOE-NASA cooperative efforts are formulated and conducted.

### A. Program Goal

The goal of the program is the effective use of NASA capabilities to accomplish specific technical and programmatic goals resulting from national energy policy.

### B. Program Strategy

The Energy Technology program uses NASA's aeronautics and space technologies, experience, and facilities to satisfy the energy research, development, and demonstration (RD&D) needs of DOE and other government organizations.

Application of NASA's capabilities follows a two-step approach. First, NASA field centers and Headquarters identify emerging requirements for energy technology, verify NASA's capabilities to effectively support the program needs of DOE and other agencies, and prepare soundly conceived plans to develop the energy technology required. NASA "seed" money and manpower are used within approved areas of emphasis. This approach is important because definitions of energy problems and their possible solutions change as the national perception of energy needs and options becomes more clearly defined, and because NASA's aeronautics and space capabilities continue to develop and expand.

The second step in the approach is for NASA, after approval of a project by the responsible agency, to perform the needed RD&D using funds provided by the approving agency. Projects originate either from the NASA-sponsored planning discussed above or from ideas conceived by other agencies. In either case, the RD&D programs and their funding are by agreement with the appropriate agencies. This approach permits NASA to continue to be responsive to national energy program needs, wherever they evolve.

### C. Program Content

The Energy Technology program consists of activities funded in whole and in part by NASA, and activities conducted by NASA for other agencies on a reimbursable basis.

#### 1. NASA-Funded Activities

NASA-funded activities concentrate on specific technologies that show potential to satisfy emerging requirements of other agencies. Examples follow.

##### a. Small Dispersed Solar System Applications

Solar energy technology promises early benefits for remote areas that have ample sunshine but little capital to import expensive fuels for conventional

power systems. This market for solar equipment could be a stimulus to commercialization of the solar industry in the United States. Consequently, we initiated in 1979 a study to explore more than 90 potential sites for solar system demonstrations in the United States, the Caribbean area, and Central and South America. On the basis of that evaluation, we selected 15 sites for more detailed analysis of energy requirements and for development of plans to satisfy those requirements with existing solar energy equipment. We are submitting those plans to implementing agencies such as DOE and the Agency for International Development for the development of reimbursable projects. The first, a joint DOE-Mexican government project, has already been initiated in 1980.

When the designs for the fifteen sites are complete, we will determine if development of fixed-size solar equipment modules is a practical and expeditious way to reduce the costs of system design and installation. This Small Dispersed Solar System Applications activity could lead to significant reimbursable projects.

**b. Bioenergy**

Bioenergy is one of the more promising sources of renewable energy and is receiving increased attention within DOE, Congress, and the energy community. This year, we have started applying our experience in bioenergy-related technologies to identification and development of advanced bioenergy concepts. In this investigative and experimental activity, we will develop a capability to make important contributions to future DOE programs. We will fund this activity until 1982, at which time we will reappraise our further involvement.

**c. Ocean Thermal Energy Conversion (OTEC)**

DOE has an OTEC program whose objective is to develop technology for using the solar energy stored in the oceans to produce electric power. The oceans are exposed to approximately 70 percent of the solar energy reaching Earth's surface. Consequently, their energy potential is enormous and could be a vast, continuous, renewable source of electric power. NASA has had extensive successful experience in developing and managing large hardware programs similar in magnitude and complexity to those expected to be required for converting the solar energy stored in the oceans to electric power. We will initiate in 1981 studies to determine how NASA's capabilities can best be applied to OTEC. The potential importance of OTEC to achievement of the Nation's energy goals may provide a unique opportunity for application of existing NASA skills and facilities.

**d. Solar Rankine Applications**

The dwindling availability and rising costs of non-renewable energy resources are creating an urgent need for development of alternate sources for the production of power. One promising source is solar-powered Rankine-cycle engines we are developing for DOE in our program, Solar Heating and Cooling Development for Demonstration. We have already used engines from that program as the primary providers of shaft horsepower to solar heating and cooling systems with capacities up to 75 tons and input temperatures of

less than 300°F. In 1981, we will determine the feasibility of increasing the size of current solar-Rankine devices to generate electricity in megawatt quantities or comparable levels of shaft horsepower. Our initial emphasis will be on the economics of those devices and on critical factors in their development.

e. Critical Technology

Technology advances in energy-efficient power systems depend on continuing improvements in areas of technology such as combustion and materials. The fundamental R&T element of NASA's Aeronautics program is providing technology bases for two activities we will conduct in 1981, continuing investigation of ways to automate the deposition of ceramic coatings on gas-turbine blades and initial investigation of concepts for achieving clean combustion of heavy oils by use of catalytic combustion processes.

f. Fossil Fuel Power Generation

We are exploring concepts that could provide power-generation systems having greater efficiency and an ability to burn a variety of fuels. In 1981, we will continue to study the use of injected steam to increase the efficiency of an existing large industrial gas turbine, and to study and analyze technologies related to the components and operating cycles of Stirling engines. The Stirling engine is a potentially very efficient power source with a multifuel capability. We plan to increase our understanding of its technology and of its characteristics for a variety of applications. We also will finish validating the concept for a simple, low-cost Stirling engine for use in university research.

g. Fossil Fuels

Increasing use of coal is a major objective of the Nation's energy program. NASA is contributing to that objective by evaluating concepts for converting coal to environmentally acceptable fuels. We are investigating concepts for cleaning coal before burning it and for increasing the yield of coal liquefaction processes. In addition, we are evaluating systems approaches for use in relatively near-term demonstrations of plants for conversion of coal to gaseous fuels.

h. Ground Transportation Systems

This program seeks to identify and verify systems concepts and component technologies that could increase the energy efficiency of ground transportation systems. It currently is investigating concepts for improving the management of urban traffic flow through use of microelectronics, sensors, data systems, and communications.

i. Industrial Energy Conservation

We are analyzing industrial processes that have high energy demands to determine whether plant and process modifications could provide significant energy conservation. We are considering process and sensor technologies for the food processing industry, for the recovery of materials such as rubber, and for application to automation techniques for the primary metals industries. We will assess the opportunities for reimbursable projects on the basis of the potential we can identify for energy conservation.

## j. Electrical Utility Systems

NASA's expertise in space communications and in control and information systems could help electric utility companies solve the significant problems facing them in implementing diverse new technologies for power generation and related control systems. We will work with representative utility companies to clarify their problems, define their requirements and institutional issues, and identify related technologies in power generation, communications and control, and power storage. We will expand our activities in 1981 to develop an overall utility-systems perspective and to identify workable technology options and implementation strategies. We will decide by the end of 1982 whether a potential for reimbursable work exists. If a potential does exist, we will, in 1983, continue identifying critical needs for technology that we can satisfy on a reimbursable basis.

## 2. Activities Partly or Entirely Funded by Other Agencies

The second step in NASA's approach to energy technology is to perform R&D that is funded partly or entirely by agencies expected to have primary responsibility for continuing application of the technologies developed. Our current activities in this category are described below.

### a. Solar Terrestrial Systems

The objective of this program is to assess technologies related to Earth-based conversion of solar and solar-derived energy and to investigate energy storage technologies. Current work is described below.

#### (1) Solar Heating and Cooling

This DOE multiyear program seeks to develop, for residential and commercial structures, solar heating and cooling systems and subsystems that are cost-effective, reliable, and commercially acceptable, and to demonstrate those systems and subsystems under a variety of climatic conditions. It consists of three major activities:

- o Completion of development of solar heating and cooling systems that are essentially state of the art but are not yet qualified for use in planned demonstrations in residential and commercial structures. We will procure improved systems in 1980 and then field test them into 1982. DOE intends to fund additional steps toward commercialization through 1985.
- o Demonstration by early 1981 of available solar heating and cooling systems and subsystems in commercial applications.
- o Provision, through 1983, of technical management assistance to the DOE program to demonstrate solar heating systems in federal buildings. We will supply solar information to other agencies, evaluate proposals, manage projects selected by DOE, and report results.

#### (2) Photovoltaic Conversion Systems

This program consists of three components.

(a) Photovoltaics Technology Development and Application

We have overall management responsibility for this DOE program, conduct its Low-Cost Solar Array (LSA) project, and manage its Photovoltaic Stand-Alone Applications project. The purpose of the LSA project is to develop, by 1986, an ability to manufacture low-cost, long-life photovoltaic modules. Our objectives are production rates permitting economies of scale that will provide a cell price of \$0.70 per peak watt in 1980 dollars, module efficiency greater than 10 percent, and operating lifetimes greater than 20 years. A key milestone is demonstration of technology readiness at the end of 1982. The purpose of the Photovoltaic Stand-Alone Applications project is to develop and conduct experiments to demonstrate cost-effective applications of near-term, stand-alone photovoltaic systems. Those experiments are to be conducted jointly with potential users in a manner most likely to stimulate markets, especially international markets.

(b) Federal Photovoltaics Utilization Program (FPUP)

This program fosters conditions to accelerate growth of the photovoltaic industry by demonstration of solar cell systems in federal facilities, use of life-cycle costing, and acquisition of useful performance data. The three remaining FPUP procurement cycles will lead to increasingly larger systems, applications with high potential for success, life-cycle cost effectiveness, and great benefits for the photovoltaic industry.

(c) Photovoltaic Development and Support

We manage this program for the Agency for International Development. Its objective is to design, develop, and deploy photovoltaic power systems for selected applications in rural areas of developing countries. It is coordinated with DOE in the interest of increasing the worldwide use of photovoltaic power systems as decentralized renewable sources for electricity.

(3) Wind Turbogenerators

We manage a major segment of DOE's Wind Energy program; namely, the development of large, horizontal axis, wind turbogenerators (WTGs). Ensuring that WTGs have potential for cost-effective commercial operation will require demonstration of a number of them in realistic applications. Five are already in operation. They range in power from 100 kilowatts electric (kWe) for the WTG near Sandusky, Ohio; through 200 kWe for the WTGs at Clayton, New Mexico, Culebra, Puerto Rico, and Block Island, Rhode Island; to 2 MWe for the WTG at Boone, North Carolina. This year, a fourth 200-kWe WTG will be in operation in Hawaii and a 2.5-MWe WTG will be in operation in the Columbia River Gorge in Washington. The 2.5-MWe unit will be the largest of its kind ever built.

We initiated in 1979, at the request of the Water and Power Resource Services of the Department of the Interior, a development project under which we will manage construction in 1981 of a multimegawatt WTG at Medicine Bow, Wyoming. If that "System Verification Unit" is successful, as many as 50 units may be constructed there.

We will initiate this year two projects under which contractors will design, develop, and construct two low-cost WTs based on advanced technology. One will produce hundreds of kilowatts of power and the other will produce at the megawatt level. Both will first operate in 1983.

#### (4) Energy Storage

Under DOE's program to develop electrochemical processes for storing electrical energy, we are developing, demonstrating, and evaluating a novel liquid-electrode battery called the Redox Flow System. Our objective is Redox systems large enough to provide operating experience and cost data adequate for the design and construction of commercial systems capable of satisfying the storage needs of two important applications.

Those applications span the wide range of power requirements of potential Redox applications. The first, storage of energy generated by photovoltaic and WTG systems, imposes requirements at the lower end of the range -- multikilowatts, storage duration of months, and 30 to 40 hours of discharge at rated power. The second, the leveling of electric utility loads, sets the requirements for the higher end of the range -- multimegawatts and storage duration of 5 to 10 hours.

Laboratory tests of multicell Redox systems and components indicate that they can meet the needs of the first application at the current level of technology, but that further improvement of technology will be required for the second application. We plan to select in 1981 three contractors to design and build six engineering prototype systems. We will use those prototype systems in field tests at several sites in 1983. Initial tests will be with 5- to 10-kW systems and will be followed by tests with 100-kW modules. Both of those sets of tests will be for the applications involving photovoltaics and WTs. The contractors will begin in 1982 to design and construct two 1.0-MW modules for the utility load-leveling application. The goal for delivery of those two modules is 1985.

#### (5) Solar Thermal-Electric Conversion

We are responsible for an important part of DOE's Solar Thermal-Electric conversion project. The objective of that project is to develop point-focusing power generating systems that are cost-effective. Since 1977, we have supported DOE planning and have let over 40 technology development contracts. The first test-bed systems are parabolic solar collectors now operating at the Jet Propulsion Laboratory's test facility at Edwards Air Force Base, California. Plans call for two installations in 1983, a 100-kWe unit at Yuma, Arizona, and a 1-MWe unit in a small community at a site not yet specified.

#### b. Conservation and Fossil Energy

This program area develops technologies to improve the efficiency of automotive propulsion and stationary power systems and of methods for extracting coal and converting it to clean gaseous and liquid fuels. Its current activities are described below.

(1) Magnetohydrodynamics (MHD)

We have been participating in DOE's program to develop direct coal-fired MHD systems by providing studies that characterize systems for utility applications and that analyze critical subsystems. Recently, our responsibilities have been expanded to include development of a 50-MW<sub>th</sub> (megawatts thermal) MHD power train. We are also responsible for managing the definition phase up to Title I for the Engineering Test Facility, which is to demonstrate a 250-MW<sub>th</sub> power train.

(2) Advanced Conversion Technology

We are managing for DOE a long-term project to develop technology for large gas-turbine engines. We have initiated development of technology for gas-turbine combustors and coating materials to support DOE's goal to provide to both the industrial and the utility sectors a capability for using minimally processed, coal-derived, liquid fuels while satisfying environmental standards. This activity is being expanded to include responsibility for gas turbine technologies for DOE's near-term project to develop combined-cycle systems for use by utilities. That project will involve gasification of coal to provide fuel to gas turbines driving electric generators. The second part of the combined cycle will be production of steam with the waste heat from the gas turbines and use of that steam to drive steam turbogenerators to produce additional electricity.

(3) Continuous Combustion Engines

We are managing DOE's program to develop continuous-combustion automotive engines. Our objective is to develop, by 1985, technology for automotive gas-turbine and Stirling engines that will meet the Environmental Protection Agency's emission goals, be 30 percent more efficient than spark-ignition engines, and be able to use a variety of fuels. Our responsibilities include planning and managing a number of industrial contracts and doing the in-house testing, design studies, and research tasks essential for accomplishing that objective. We awarded a major contract in 1978 for development of an advanced Stirling engine that will be this country's first one designed for installation in an automobile. Each major U.S. automobile manufacturer has recently completed studies of conceptual designs for advanced gas turbines, and last year we selected two industrial teams for 1980 contracts to develop two advanced gas turbine engines. A key part of this program is development of ceramic components.

(4) Electric and Hybrid Vehicles

We are managing the research and develop elements, except those for batteries, of DOE's Electric and Hybrid Vehicle program. The principal elements are development of propulsion technology and advancement of vehicle-level technology. In 1980, we will finish testing two newly developed, near-term, electrically propelled vehicles and start developing hybrid vehicles that will use a combination of internal-combustion and electric propulsion.

(5) Fuel Cell Systems

We are managing development of technology for phosphoric acid fuel cell systems applicable both to power generation by electric utilities and to total energy systems for commercial and residential uses. A further objective is to develop additional system suppliers to assure a competitive supplier industry.

### C. Space Utilization Systems

This program area develops technologies for exploiting the unique characteristics of space to help solve energy-related problems on Earth. We will continue to survey and evaluate proposed concepts for the use of space systems and resources to aid in the delivery and use of solar energy on Earth. We plan to examine concepts for devices such as orbital reflectors and lunar-based power systems and for techniques for controlling and managing energy systems. Current reimbursable work includes the two activities described below.

#### (1) Nuclear Waste Management

DOE is assessing methods for isolating wastes from nuclear reactors. As part of that assessment, we are studying isolation of nuclear wastes in space -- with assistance from DOE in analyzing technology related to processing, packaging, and transporting wastes on the ground. Our study includes concept and systems definition, impact assessment, economic comparison, and benefit analysis. With continued support from DOE through 1983, it could lead to definition of a preferred system, complete in all major aspects, for isolating wastes safely in space, as well as to a basis for decisions on proceeding with development of the preferred system.

#### (2) Satellite Power System (SPS)

The SPS project is a DOE-funded activity jointly managed by DOE and NASA under written agreements. NASA is responsible for defining all technical systems, while DOE is responsible for assessing the systems from the standpoint of environmental and socioeconomic factors, including comparative evaluation of SPS with alternative energy sources. DOE's assessments will be the basis for determining whether a focused program on SPS technology is technically and economically justified. Initiation in 1981 of a ground-based exploratory research and development program is expected to remove -- by analysis, design, and experiment -- the technological, engineering, environmental, and economic uncertainties that must be resolved before a decision can be made to proceed with an SPS development program.

### D. Schedule and Funding

Table 14 shows the phasing of the Energy Technology program and Figure 29 shows the program's funding requirements. The run out of the NASA budget provides level-of-effort funding at \$4 million per year. The funding shown for current reimbursable activities is NASA's best estimate for the run out of those activities. Total funding can be expected to change significantly as new reimbursable programs come into being. The upper curve illustrates the potential effect of new energy legislation that would result in additional reimbursable programs.

TABLE 14 -- ENERGY TECHNOLOGY PROGRAM SCHEDULE

PROGRAM	RESPON- SIBLE FIELD CENTERS*	PROGRAM PHASE		ADDITIONAL IMPORTANT DATES
		INITIA- TION	COMPLE- TION	
<u>SOLAR TERRESTRIAL</u>				
Solar Heating and Cooling	MSFC	Ongoing	--	Installation of developed systems -- complete 1980; commercial demonstration installations -- complete 1981; federal buildings project -- complete 1983
Photovoltaic Conversion Systems	JPL	Ongoing	--	Encapsulation materials process improvements -- complete 1981; silicon materials experimental unit -- operate 1982; technology readiness -- demonstrate 1982; silicon sheet equipment development -- complete 1983
Wind Turbogenerators (WTGs)	LeRC	Ongoing	--	Fourth 200-kWe WTG, in Hawaii -- operate 1980; 2.5-MWe WTG in Washington -- operate 1980; Water and Power Resources Service WTG at Medicine Bow, WY -- operate 1981; advanced low-cost MWe and 100-kWe WTGs -- operate 1983
Redox Flow System	LeRC	Ongoing	--	Evaluation and cost analysis of 2-kW demonstration module -- complete 1980; MW module development -- initiate 1980
Solar Thermal Electric Conversion	JPL	Ongoing	--	First-generation system -- test 1981; first 100-kWe unit -- install 1983; 1-MW unit for small community -- install 1983
<u>CONSERVATION AND FOSSIL ENERGY</u>				
Industrial Gas Turbines	LeRC	Ongoing	TBD	Data to support liquid-fuel engines development decision -- 1980

\*JPL = Jet Propulsion Laboratory  
MSFC = Marshall Space Flight Center

LeRC = Lewis Research Center

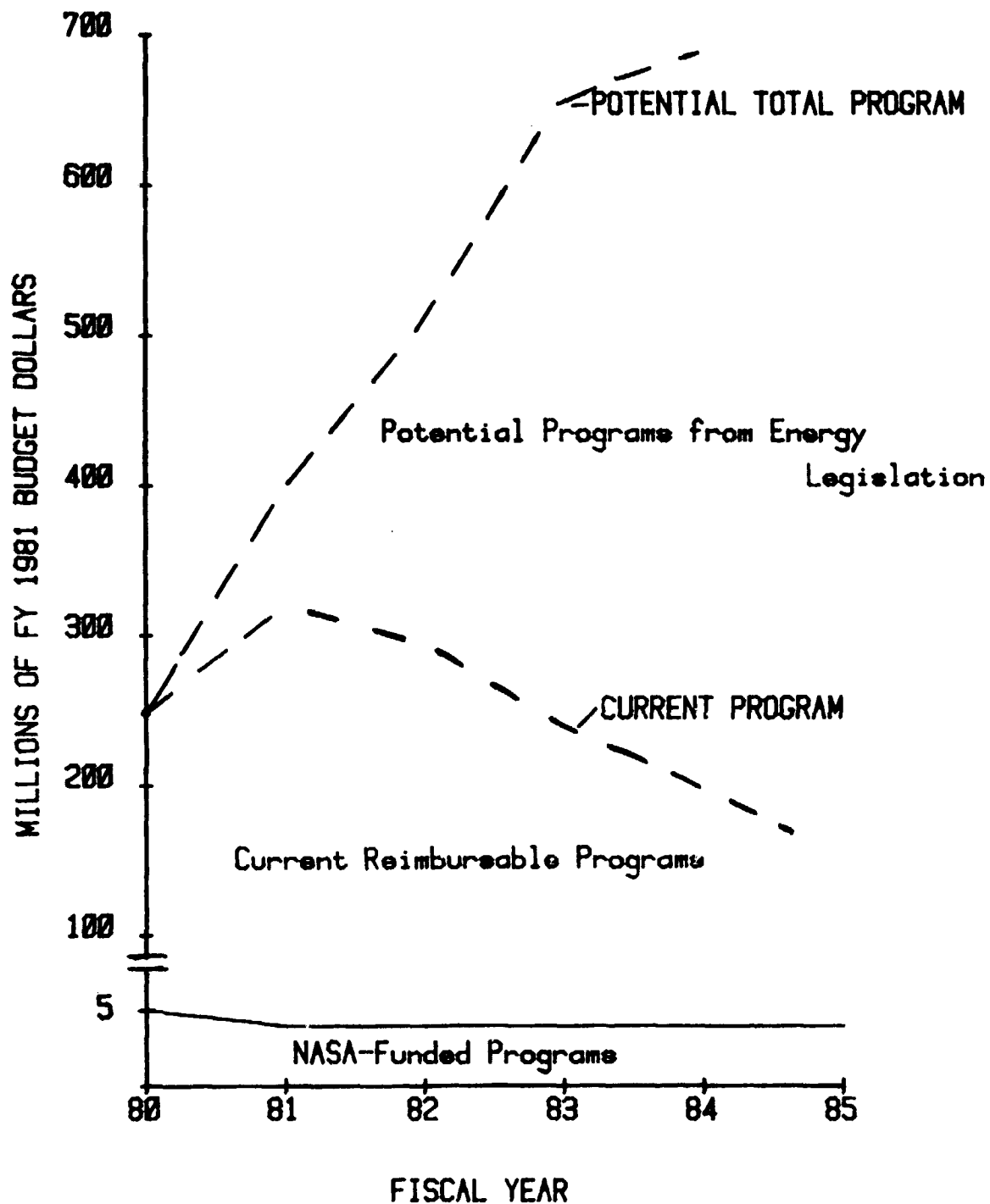
TABLE 14 -- ENERGY TECHNOLOGY PROGRAM SCHEDULE (CONTINUED)

PROGRAM	RESPON- SIBLE FIELD CENTERS*	PROGRAM PHASE		ADDITIONAL IMPORTANT DATES
		INITIA- TION	COMPLE- TION	
CONSERVATION AND FOSSIL ENERGY (CONTINUED)				
Advanced Propulsion for Ground Vehicles:				
Automotive Gas Turbines	LeRC	Ongoing	1985	First experimental engine (MOD 1) on dyna- mometer -- 1983; experimental engine (MOD 2) in vehicle to Environmental Protection Agency (EPA) -- 1985
Automotive Stirling Engine	LeRC	Ongoing	1984	First experimental engine (MOD 1) on dyna- mometer -- 1981; experimental engine (MOD 2) in vehicle to EPA -- 1984
Electric and Hybrid Vehicles	LeRC, JPL	Ongoing	TBD	Improved Electric Test Vehicle, ETV-1 -- test 1981; near-term hybrid vehicle -- test 1983
Phosphoric Acid Fuel Cell Systems	LeRC	Ongoing	TBD	40-kW system -- check out 1980; air-cooled stack -- evaluate 1981
SPACE UTILIZATION				
Nuclear Waste Management Definition	MSFC	Ongoing	--	Safety assessment of preferred concept -- complete 1980; NASA-DOE program continuation -- decide 1981
Satellite Power Systems (SPS) Ground-Based Exploratory Development	MSFC, JSC	1981	--	Concept definition and evaluation programs -- complete 1980; DOE-NASA recommendation on future SPS effort -- 1980

\*JPL = Jet Propulsion Laboratory  
JSC = Johnson Space Center

LeRC = Lewis Research Center  
MSFC = Marshall Space Flight Center

FIGURE 29.  
ENERGY TECHNOLOGY PROGRAM FUNDING



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## VII. SPACE TECHNOLOGY PROGRAM

Timely investment in technology is beneficial if the technology enhances the results obtained by current and planned missions or if it enables missions that require capabilities beyond the anticipated state of the art. Consequently, in planning its space technology program, the Office of Aeronautics and Space Technology (OAST) consults extensively with the other program offices in the Headquarters to determine both the content and the schedules of their current and projected programs. OAST also maintains cognizance of the benefits that advances in technology could contribute to NASA's potential space activities.

Research and development to advance technology evolves from concept to laboratory, then to flight demonstration, and eventually to program application, and is a long-term process of incremental progress along both planned and unexpected paths. Electric propulsion provides an example. It was conceived in the late 1950s, initiated as a laboratory development program in the 1960s, and proven to be a feasible concept in two experimental flight demonstrations, SERT I and II. SERT successes generated an endorsement from the other program offices for OAST to proceed with a focused technology program to provide a basis for the Solar Electric Propulsion System (SEPS). The results of this systems technology effort will culminate in two experiments to prove flight readiness. A large, 12.5-kW solar cell array developed for SEPS is being readied for flight demonstration. It will be carried into space by the Shuttle and unfurled from the Shuttle's cargo bay for the demonstration. In the other demonstration, an 8-centimeter engine operating on the ion propulsion principle will be flown in the Department of Defense's flight test of its Teal Ruby system.

Those technology programs have provided a very substantive basis for proceeding with development of SEPS. In addition, they have provided unexpected spin-offs. The 12.5-kW solar cell array mentioned above will serve as the power generating element of the Power Extension Package that the Office of Space Transportation Systems (OSTS) plans to develop to increase the Shuttle's stay time in space. It is also evolving as the technological basis for the 25-kW Power System and the Science and Applications Platform that are also in the OSTS plan.

Use of technology to enable a mission is evident in the Shuttle program. Fundamental enabling technology that allowed NASA to undertake that program was related to lifting-body vehicles, high-pressure liquid-fuel engines, reusable surface-insulation materials, and solid-fuel motors.

As the above examples show, the progress of technology over a period of years can be truly impressive, and can lead to important discoveries not originally foreseen.

### A. Program Goal

The principal goal of the Space Technology program is to generate advanced technology for application in cost-effective and reliable space systems that are of public benefit and that support national needs. The program is designed to support and enhance approved space programs, to provide technology options for planned programs, and to enable potential programs.

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## **B. Planning Assumptions**

The Space Technology program is based on the following assumptions regarding needs and responsibilities:

- o NASA will continue to be the Nation's principal source of advanced research and technology for civil space programs.
- o NASA will provide research and technology for military space programs if requested to do so, and if the work to be done is agreed to in specific, joint-agency actions.
- o The Offices of Space Science, Space and Terrestrial Applications, Space Tracking and Data Systems, and Space Transportation Systems will continue to conduct supporting research and technology development for their approved and planned flight projects.
- o The Shuttle-Spacelab will become available as a facility for space research in Earth orbit and for flight qualification of development hardware.
- o Space missions after 1990 will have four major goals:
  - Use of space research and development in, for example, processing of materials, construction of large space structures, and evaluation of sensor systems
  - Exploration of the universe
  - Provision of global services such as worldwide communications and weather and climate forecasting
  - Transportation to, within, and from space.

## **C. Space Technology Planning Process**

There are two vital preliminary steps in the development of OAST's space technology plans -- determination of the needs of planned and forecast programs for new technology and discovery of opportunities for technological innovation that will enable otherwise unachievable missions. The process followed in taking those steps, and in deciding which of the possible technology programs will be funded, employs the committee types of activity and the procedural methods described below to collect, generate, organize, and establish priorities for a full array of potential programs that must compete for the limited funding available.

### **1. Committee Activities**

This type of activity includes the work of committees, teams, working groups, panels, and other similar assemblies of people, some of which are described below. It is concerned principally with the formulation of programs that become candidates for inclusion in OAST's space technology plan. The assemblies are ad hoc, for the most part, and are organized, restructured, and dissolved in response to perceived needs.

a. Research and Technology (R&T) Assessment Teams

R&T assessment teams are composed of technical program managers from NASA Headquarters and the NASA field centers. In the past three years, R&T assessment teams have provided advice in the form of their consensus on the best allocation for the Agency's space R&T resources.

b. Cross-Cutting Technology Teams

For a technology area of importance to more than one program office, a cross-cut team consisting of representatives of all the interested offices is established to coordinate the plans and activities of all the offices involved in the area. Cross-cut teams have made significant contributions during the last two years in the areas of large space structures, space power, chemical propulsion, communications, sensors, and data management.

c. Center Working Group

A working group composed of representatives from NASA's field centers provided a major portion of OAST's plan for R&T for advanced space transportation systems.

d. Space Systems and Technology Advisory Committee (SSTAC)

SSTAC is a committee of the NASA Advisory Council, which is composed of knowledgeable persons from universities, industry, and government agencies. SSTAC and its ad hoc subcommittees recommend changes, additions, and deletions in the space R&T program that are valuable, especially in that they provide a broadened perspective.

e. NASA and Air Force Systems Command Inter-Dependency Working Group

This working group meets regularly to exchange information on the two organizations' accomplishments in and plans for space R&T. The activity of this group has led to many joint efforts that have produced valuable benefits. An example is the Space Charging program, which is investigating the disruptive static electrical charges that can build up on the surfaces of satellites at high altitudes.

2. Procedural Methods

a. Space Systems Technology Model

The Space Systems Technology Model is a fully traceable system for:

- o Specifying, for the next ten years, the technology requirements of a fully validated set of approved, planned, and candidate space programs and missions
- o Forecasting space technology trends and their relevance to potential systems
- o Identifying space missions and technologies that are somewhat speculative in nature and whose potential would be realized ten or more years hence

- o Analyzing mission trends, technology forecasts, and innovation opportunities to provide a basis for setting priorities on possible R&T activities and for preparing space R&T plans.

b. Ad Hoc Survey

The Ad Hoc Survey is a process for obtaining information on technology needs that we initiated as an aid to our planning for 1981 through 1985. It involves polling the program offices for their perceived critical needs for technology and for the relative priorities of those needs.

D. Program Content

1. Principal Elements

The Space Technology program is structured into four major program elements: Disciplinary Research and Technology, Information Systems, Spacecraft Systems, and Transportation Systems.

2. Disciplinary Research and Technology

The Disciplinary R&T program element builds a technology foundation for use in space projects in the other three program elements. It seeks to understand the basic physical and chemical phenomena of matter and processes and to transform novel ideas into practical working innovations. It searches for new and improved capabilities by conducting research in a wide range of engineering and scientific disciplines such as aerothermodynamics, materials science, structures, propulsion, power, electronics, and automation. The research is performed by NASA scientists and engineers and by university and industrial researchers. This diverse participation leads to extensive interaction and produces a dynamic interchange of information, talents, and resources. Some of the discipline areas included in the 5-year plan are described below.

a. Structural Analysis and Design

We plan to develop structural analysis and design techniques, optimal methods for sizing and costing structures, and techniques for controlling the static and dynamic responses of structures. We will emphasize concepts for lightweight construction, structural joints, automated construction techniques, and integration of service and distribution functions such as electrical power and thermal and environmental control.

b. Dynamics of Structural Systems

We plan to develop analysis and test methods for predicting the dynamic and acoustic responses of structural systems. We will refine existing methods for determining the coupling between vehicles and their payloads and develop advanced techniques for measuring dynamic responses and for reducing the resulting measurement data in flight. We will include studies on the alleviation and control of the dynamic effects of loads.

c. Molecular Structure

Knowledge of molecular structure allows analytical techniques to be used in place of laboratory experimentation, thereby considerably reducing the

cost of research. Use of solutions to the complex equations of molecular structure has already made major contributions to our ability to understand the chemical reactions that destroy ozone in Earth's atmosphere, to predict the radiative heating resulting from entry into planetary atmospheres, and to determine the density of stellar clouds. We plan to continue our fundamental research in computational chemistry to improve our understanding of basic physical and chemical properties of gases, solids, and surfaces.

#### d. Space Electrical Energy

The Space Power and Electric Propulsion R&T program will continue and be augmented. Its aim is to provide a basis for advances both in low-thrust, high-specific-impulse electric propulsion systems and in methods to generate, store, and manage electrical energy in space. Specific activities that will be conducted include the following:

- o R&T in photovoltaics to improve conversion efficiency, reduce mass and cost, and increase operating life. We will focus on demonstrating the feasibility of silicon cells with a conversion efficiency of 18 percent and of thin gallium arsenide solar cells. We will also continue to seek a better understanding of radiation damage to and thermal annealing of solar cells in order to determine how to extend their operating life.
- o Development of advanced power-management components; for example, transistors, inductors, and power transfer devices.
- o Initiation of a joint program with the Air Force aimed at understanding and controlling the interactions of high-voltage space plasmas.
- o Extension of the performance of mercury ion thrusters to provide higher power densities and thrusts, and broadening of the range of useful specific impulse. We will also lay the technical foundation for inert gas (argon and xenon) thrusters.

#### e. Electronics

Our fundamental electronics program is structured to increase the scientific and operational capabilities of space systems. One of the most promising activities in the program is development of concepts for onboard, automated operations. That activity will continue. Other activities included in this plan are laboratory experiments to investigate new ideas for techniques to increase energy conversion efficiency; a search for concepts for detectors and sensors spanning the entire electromagnetic spectrum; development of technology for making large-scale, high-speed integrated circuits for application to long-life devices for use in unique space programs; and development of technology for other new devices that will have use in the future.

### 3. Information Systems

This program element develops capabilities for acquiring, processing, and disseminating data in a form responsive to specific needs arising in the

Agency's science and applications programs. Its objective is to provide more effective acquisition, processing, and dissemination of information from space platforms by providing broader synoptic coverage, wider spectral range, more rapid access to useful information, and, ultimately, systems with lower costs. Its major components are communications R&T for the Office of Space and Terrestrial Applications (OSTA), and sensing and data reduction and dissemination for OSTA and the Office of Space Science. In the early years of this 5-year plan, we will emphasize efficient sensing systems and data systems.

a. Efficient Sensing Systems

Our objective for sensing systems is to increase substantially the information returned from space missions, while reducing costs, by improving the spatial, spectral, temporal, and radiometric resolution of sensor systems. We plan to initiate in 1982 development and demonstration of technology readiness for passive and active microwave sensors, high-resolution optical sensors, and wide-band infrared sensing systems. Those devices are required for astrophysics, planetary, and Earth observation missions. We plan to initiate in 1983 R&T for "smart" sensing systems embodying such techniques as placing adaptive microprocessor chips directly in sensor focal planes. Other planned R&T will address multifunction capabilities for sensing systems to enable the systems to provide, for example, all-weather, 24-hour, high-resolution measurements of ocean salinity, temperature, surface winds, and ice coverage.

b. Data Systems

The overall objective of our data systems program is to improve significantly our effectiveness in processing and distributing space information. During the 1981-1987 planning period, we will expand our development of technology for real-time data management.

c. Communications

Our principal objective for communications is development of technology for advanced components of communications satellites, including multibeam antennas, power amplifiers, switching circuits, and low-cost receivers. We plan to integrate, by 1983, advances in communications technology developed in the Disciplinary Research and Technology program in order to verify at the system level the capabilities of communications systems to provide high data rates for both space-to-space and space-to-ground applications.

4. Spacecraft Systems

This program element develops technology for structures, materials, guidance, navigation, control, planetary atmosphere entry, space power, onboard propulsion, and spacecraft assembly, servicing, and maintenance. It has a systems orientation and, during this planning period, will deal primarily with the large space systems that will serve as centralized bases for operating and supporting multisensor and multifunction space systems in the late 1980s and in the 1990s. Payloads that can share those large, maintainable, refurbishable platforms and their services and supplies are expected to have lower life-cycle costs and to be better able to operate with the Space Shuttle.

#### a. Structures

We will concentrate our R&T for large space systems on development of structures, of techniques for joining components to form the structures, and of methods for controlling the shapes, positions, and orientations of the structures in space. Examples of structures that are of interest are trusses upon which equipment will be mounted, secondary structures such as booms and panels to carry solar arrays and heat dissipation surfaces, and structures whose surfaces are used for focusing electromagnetic waves and therefore must have their geometry accurately controlled. That last kind of structure includes antennas, mirrors, and solar concentrators. One specific activity in this part of our Spacecraft Systems program is development of technology for the very low thrust Ion Auxiliary Propulsion System that will be used to keep structures accurately on station.

We will continue to seek structural designs that will allow use of automated and human construction and maintenance services, both in situ and remote, as efficiently and effectively as possible. We plan to augment our R&T for large space structures in 1982 to provide more emphasis on development of structural concepts and on in-space experimentation needed to characterize key factors such as structural damping, control system performance, and assembly techniques. Our ground test program will provide by 1983 a validated data base that will support development of the deployable antenna (50 to 100 meters in diameter) mentioned in the Large Space Structures Systems Engineering section of the Office of Space Transportation Systems' plan in this report. Later in the planning period, we will develop a similar validated data base for deployable and machine erected space platforms with dimensions as large as several hundred meters.

#### b. Electrical Power and Thermal and Environmental Control

We plan to expand our Spacecraft Systems program in 1982 to include development of technology for subsystems to provide electrical power, heat transfer and dissipation, and environmental control. We will seek substantial decreases in the costs of solar arrays, substantial increases in the capacities of energy storage devices, effective means for power management, and automation of thermal control. If fundamental R&T for high-energy lasers is successful, we will initiate development of space-to-space transmission of electrical power. We also plan to start development of long-range technology required to determine the feasibility of a high-power, heat-pipe-driven, thermal conversion system potentially applicable to solar system exploration, nuclear waste disposal, lunar-based power generation, and advanced solar-thermal systems. That development activity has the additional value that it is compatible with a possible mid-1980s decision to initiate development of a nuclear-electric propulsion system.

Late in the 1981-1985 period, we plan to develop technology for automated systems for use aboard satellites and in tele-robotic service equipment to assemble, maintain, and repair space platforms and the systems mounted on them.

#### c. Planetary Atmosphere Entry

Our planned analytical and experimental activities will improve our understanding of the aerothermodynamic and materials behavior of entry bodies and enable us to develop better predictive design techniques. In

addition, our R&T related to entry into planetary atmospheres will permit future entry systems to have thermal protection systems with minimum weight. The result will be a potential for heavier payloads or even the ability to accomplish a mission that would not otherwise be possible.

d. Long Duration Exposure Facility (LDEF)

LDEF is a free-flying spacecraft that the Shuttle will deliver to space and return to Earth. It will carry 71 trays of passive experiments for long-term (6- to 9-month) exposure to the space environment. The current schedule for Shuttle flights includes launch of LDEF in March 1982.

e. Shuttle-Spacelab Experiments

The Space Shuttle and Spacelab will provide unique opportunities for experimentation in support of the Space Technology program. We are developing a set of technology experiments to be flown on several of the Shuttle's orbital flight tests, including OSTA I and II, whose payload accommodations are assigned principally to the Office of Space and Terrestrial Applications. That set of experiments will also be part of the payload complement of the first three Spacelab flights. Some other experiments have objectives that will require flight on free-flying spacecraft.

5. Transportation Systems

This program element currently has three principal objectives: to develop technology for a space transportation system that will be more fully reusable than the Shuttle and have substantially lower operating costs; to perform Shuttle flight experiments centered principally in our Orbiter Experiments Program; and to support Shuttle development in specific areas in which we have competence. Current areas in which we are providing support by developing technology are structures and materials, chemical and electric propulsion, and aerothermodynamics. We will augment that basic activity by conducting flight experiments aboard the Shuttle both in our Orbiter Experiments Program and in Spacelab.

a. Structures and Materials

Our current Transportation Systems program includes technology development for primary structures fabricated from graphite-polyamide (Gr-PI) composite materials. Demonstration of the technical feasibility of Gr-PI primary structures will make possible major reductions in the weight of Earth-to-orbit transportation systems.

b. Propulsion

Propulsion systems using large liquid-fueled rockets are likely to be needed for the fully reusable transportation system mentioned above and for orbit-transfer vehicles. NASA is the Nation's principal agent for that type of propulsion and will be depended on to maintain the pace of technology development for it at a level that will maintain a competitive industrial base. Consequently, we plan to augment our activity in this area beginning in 1982.

#### c. Aerothermodynamics

We will continue our program of analysis and experimentation to evaluate aerothermodynamic characteristics provided by materials, controls, and vehicle configurations more technologically advanced than those in the Shuttle. We will also continue to support Shuttle development by performing independent aerothermodynamic analyses and testing on a demand basis.

#### d. Advanced Vehicles

We recently developed an advanced transportation technology plan as a means for focusing R&T on high-leverage technology for Earth to low-Earth-orbit (LEO) and LEO to geosynchronous orbit (GEO) vehicles. We will use that plan as a basis for augmenting our Space Transportation program in 1982 to provide for R&T that will permit development of vehicles with better performance and lower operating costs. Anticipated benefits for Earth-to-LEO vehicles are lower vehicle weights and significant increases in maintainability and reusability. For the LEO-to-GEO task, we will first quantify the relative merits of low-thrust and high-thrust vehicles, especially for orbit transfer of large space structures. We will then initiate R&T in the high-payoff areas we have identified.

#### e. Atmosphere Entry

We plan to take full advantage of the opportunity the Shuttle will provide to do full-scale testing to expand and improve our current ground-based entry research. As part of our Orbiter Experiments Program, we will instrument the Shuttle Orbiter to obtain experimental data on lifting-body entry into Earth's atmosphere. We have designed instrument packages for a Shuttle infrared, leeside, temperature sensing experiment and a tile-gap heating experiment. We have also designed an aerodynamic coefficient identification package that is being integrated into the Orbiter for the Shuttle's first flight. The data we obtain from these instruments will increase the available technology in aerodynamics, entry heating effects, thermal protection, and flight dynamics, and will significantly strengthen our ability to design lifting-body entry vehicles.

#### E. Schedule and Funding

Table 15 shows the phasing of the Space Technology program and Figure 30 shows the program's funding requirements.

TABLE 15 -- SPACE TECHNOLOGY PROGRAM SCHEDULE

PROGRAM	RESPONSIBLE FIELD CENTERS *	PROGRAM PHASE		ADDITIONAL IMPORTANT DATES
		INITIATION	LAUNCH	
Long-Duration Exposure Facility (LDEF)  Spacelab Payloads  Ion Auxiliary Propulsion System	LaRC	Ongoing	1982	LDEF retrieval -- 1983
	MSFC	Ongoing	1982	Solar array test -- launch 1982
	LeRC	Ongoing	1982	Ion auxiliary engine test -- complete 1983

\* LaRC = Langley Research Center  
 LeRC = Lewis Research Center  
 MSFC = Marshall Space Flight Center

The graph displays budget trends for four main categories: Spacecraft Systems (1.), Transportation Systems (2.), Information Systems, and Disciplinary R&T. The 'TOTAL PROGRAM' is the sum of these, while the 'CURRENT PROGRAM' represents the existing budget levels. Spacecraft and Transportation systems show significant growth projections, while Information Systems and Disciplinary R&T show more modest increases or stability.

Fiscal Year	1. Spacecraft Systems	2. Transportation Systems	Information Systems	Disciplinary R&T	TOTAL PROGRAM	CURRENT PROGRAM
80	85	105	60	105	255	255
81	90	105	65	105	265	255
82	95	105	70	105	275	255
83	110	120	60	105	305	255
84	130	150	60	110	350	255
85	150	180	60	115	405	255

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## VIII. SPACE TRANSPORTATION SYSTEMS PROGRAM

### A. Foreword

After NASA's 1980 through 1984 5-year planning report was issued in the spring of 1979, the Office of Space Transportation Systems (OSTS) requested comments on its part of the plan from a number of industries, universities, and professional organizations. The majority of their comments urged OSTS to include in its planning over the next several years a longer planning horizon, the setting of specific goals, and more realism in its funding estimates. Those comments coincided with plans OSTS had in process. Delays in the Space Shuttle's schedule and the resultant effects on NASA's budget further underscored the desirability of such changes.

This 5-year plan includes the results of OSTS' first attempt to reflect the comments received. The most important of the resulting changes from the 1980-1984 planning report are as follows:

- o Except for funding estimates, the basic planning period extends to 10 years rather than 5 years.
- o The plan responds to explicitly stated goals and objectives for the program beyond that 10-year basic planning period.
- o Changes in the estimated costs and schedule for the Space Shuttle are included.

### B. Introduction

The Space Transportation Systems program consists of three major activities:

- o Design, development, test, and evaluation (DDT&E) and production of the Space Transportation System (STS) -- the combination of Shuttle, Spacelab, and Inertial Upper Stage (IUS) currently approaching operational status. Spinning Solid Upper Stages (SSUSs) being developed by industry will also be used with the STS as upper stages.
- o Space flight operations, including those with expendable launch vehicles.
- o Space systems engineering -- the evolutionary development of transportation, satellite services, and space platform capabilities.

The principal thrust of the program during the early years of this planning period will be to achieve full operational capability for the STS. As we progress toward satisfaction of that aim, we will be able to give increasingly more attention to developing the additional needed capabilities in the space systems engineering category of activity.

## C. Assumptions

### 1. Likely Environment in the 1990s

Assumptions about the state of the world in the 1990s are essential to definition of the goals and objectives of the Space Transportation Systems program and to preparation of a program plan that is appropriate and realistic. Many features of the world environment are highly variable but have great effect. Among such features with the greatest effect are those underlying the following three assumptions:

- o The "Third World" will continue to emerge and expand its power and influence, thereby creating new markets for technology and space services while increasing competition for supplying them.
- o Renewable and non-renewable resources, particularly energy, will become increasingly scarce, which will exert continuing pressure on the civilian space budget.
- o Implicit in both of these assumptions is the assumption that the need for military space technology will increase.

### 2. Implications for the Space Program

From our assumed world environment, we infer that the growth of U.S. civilian space programs in the 1990s will probably continue to be moderate and evolutionary, rather than rapid or "Apollo-like." We also infer that space projects will increasingly have to demonstrate significant economic return or perform essential services to obtain approval. Implicit value will become insufficient justification for approval except for exploration and science programs, which will continue to pursue the acquisition of knowledge but probably also will come under increasing budgetary pressure.

Those trends will inevitably lead to a need for more advanced technology, as well as for more aggregation of satellite functions in larger, multifunction "facilities" in order to capture the economies expected to result from sharing common subsystems such as structure, attitude control, power supply, and thermal control. Likely economies of scale will encourage growth in spacecraft size and mass of at least an order of magnitude during the next two decades, and will require development of techniques for deployment, erection, fabrication, and assembly of large structures in orbit. The power generated for onboard use will have to increase by several orders of magnitude.

Because of their complexity and the large number of parts they will contain, those larger, aggregated spacecraft will become increasingly subject to failures, while failures will become less and less tolerable. Long-life components and multiple redundancy will help, but provisions for in-orbit maintenance, servicing, repair, and modification will become increasingly necessary. Unmanned servicing by means of remotely controlled devices will suffice initially. However, it appears that many tasks may defy remote control because of the need for interacting manipulative, analytical, and interpretive skills. Those tasks may be performed more simply and successfully by humans. We have assumed, therefore, that it will become increasingly necessary to include human presence in space, with the optimum mix of manned and remotely controlled operations for any application yet to be determined.

We have assumed also that construction and assembly of large structures in space, establishment and operation of refueling and tending facilities for high-orbit transportation, and timely emplacement, retrieval, and repair of a host of low-altitude satellites will require human presence in space on a continuing basis. The need for human presence will exceed the abilities of the Space Shuttle in both capacity and orbital stay time, and will lead to permanently manned orbital facilities.

#### D. Goals and Objectives

The principal goals of the Space Transportation Systems program continue to be to develop and operate systems that will efficiently and effectively satisfy the space transportation and space support needs of the civil sector of the United States and, when appropriate, to make the capabilities of those systems available to others. The objectives selected to achieve those goals must ensure that differences between the postulated and actual environments will change only the rates at which the goals are achieved, and not the nature of the goals. The evolution of systems capabilities to support both the goals and the objectives must be sufficiently flexible to accommodate the rate changes. The objectives selected to meet the program's goals while satisfying those criteria are as follows:

- o To complete development of the Shuttle, Spacelab, IUS, SSUSs, and all required ground facilities, and to operate them on a routine basis by the mid 1980s
- o To develop unmanned, large, multifunction, low-Earth-orbit, Shuttle-tended, free-flying spacecraft and to operate them on a routine basis during the mid 1980s
- o To develop a manned permanent facility for research, construction, and operations in low Earth orbit, and to routinely operate it by the end of the 1980s
- o To develop, for operation by the late 1990s, permanent multifunction facilities in geostationary orbit, initially serviced remotely, then man tended, and later manned. This objective requires a major reduction in the cost of space transportation.

Table 16 summarizes the phased actions that will provide the evolution of space transportation systems to satisfy those objectives.

#### E. Program Content

##### 1. Shuttle DDT&E and Production

###### a. Space Shuttle Initial Configuration

The Space Shuttle will provide users with efficient, economical access to space, as well as with capabilities that today's expendable launch vehicles cannot supply. It is scheduled to become operational in 1982. Together with the other components of the STS (Spacelab and the IUS) and the SSUSs, it will satisfy into the 1990s the transportation needs of the operational and developmental payloads proposed for flight by many prospective users -- NASA, the Department of Defense, other U. S. Government agencies, universities, and commercial and international organizations.

TABLE 16 -- EVOLUTION OF SPACE TRANSPORTATION SYSTEMS

	1980-1985	1985-1990	1990-2000
OBJECTIVES	Routine Operation of Shuttle, Spacelab, IUS, and SSUS	Permanent unmanned, then manned, facilities in low Earth orbit	Manned geosynchronous facility
TRANSPORTATION	Bring STS to operational status Develop high-energy solar-electric propulsion system Augment Shuttle thrust to improve performance Reduce cost of space operations	Develop interim orbital transfer vehicle for cargo Improve Orbiter habitability for extended stay times	Develop orbital transfer vehicle for heavy payloads and manned sorties to and from geosynchronous orbit Develop crew module for permanent platform in geosynchronous orbit Develop Shuttle-derived heavy-lift launch vehicle
SATELLITE SERVICES	Develop capability using Remote Manipulator System (RMS) and maneuvering units to inspect and repair Orbiter insulating tiles in space Develop capability to place, retrieve, and exchange modules in satellites near Orbiter	Develop adapters, tools, and devices to enable RMS to service satellites near Orbiter Develop capability to place and retrieve satellites and replace modules in satellites remote from Orbiter	Develop remotely controlled systems for routine servicing, inspection, and retrieval of satellites remote from Orbiter and in geosynchronous orbit
SPACE PLATFORMS	Develop solar-array system to increase Shuttle electrical power and stay time Define and perform large-structures experiments Develop low-Earth-orbit, unmanned, STS-tended, free-flying power modules and experiment, materials processing, and applications platforms and modules	Develop manned facility in low Earth orbit consisting of service, habitation, logistics, flight support, and construction modules Develop and use large structures in low Earth orbit	Develop large power modules for powering platforms and for energy research Develop manned platforms for operation in geosynchronous orbit

Table 17 lists the major capabilities of the STS and the SSUSs. The baseline Shuttle will carry personnel and payloads to low Earth orbit, support them and their operations there for a nominal period of one week, and then return them to Earth. It will be able to carry into space in its large cargo bay payloads weighing as much as 29,500 kilograms (65,000 pounds) and will provide a "shirt-sleeve" environment for its crew and passengers. For some years, there will be only one class of passengers -- the science and engineering specialists responsible for the experimental work on each flight.

#### **b. Planned Improvements in Shuttle**

Some improvements will be necessary to bring the Shuttle up to its full operational specifications. The Shuttle's ability to deliver its maximum (65,000-pound) payload to orbit and to achieve its full mission duration will require extension of the operating envelope of the Shuttle's main engines and weight reductions in the External Tank and the Orbiter. The DDT&E program provides for those improvements.

The most demanding payload-trajectory combination currently expected to be flown from Vandenberg Air Force Base (VAFB) will require thrust augmentation for the Shuttle in 1984. We plan to provide that augmentation in the form of an auxiliary liquid-rocket booster. Later needs will require further uprating of the Shuttle to the 100,000-pound payload level.

#### **c. Fleet Size**

Since the decision in 1972 to develop the reusable STS to support all national space activity, both civil and military, NASA has led a continuing multiagency effort to estimate payload requirements, objectives, and levels of activity for a decade ahead. Those estimates represent reasonable expectations both for continuing programs and for programs expected to evolve in an environment of increasing dependence on space in support of national goals. We revise them continually as users define their plans more completely. For the 1981 through 1992 period, the currently estimated need is for 487 flights, as shown in Table 18.

Concurrently, we have analyzed the flight-rate capability of fleets of various sizes under realistic operating conditions. Our most recent results indicate that a fleet of four Shuttles operating from two sites, Kennedy Space Center (KSC) and VAFB, can provide an annual flight rate of 38 (for 5-day, 2-shift operation) to 53 (for 7-day, 2-shift operation). With adjustment for a lower flight rate during the build-up period, those rates will provide 380 to 520 flights during the 1981 through 1992 period. Consequently, full use of the STS is becoming increasingly certain. Its first 40 operational flights, extending through the first half of 1984, have been booked for customers from whom NASA has received "earnest money," for approved NASA payloads, and for committed Department of Defense payloads; and many additional requests for flight accommodations are in negotiation. Also, space users have increased significantly the number and depth of their studies and analyses seeking new activities in space that will exploit the Shuttle's unique capabilities.

TABLE 17 -- STS CAPABILITIES

SHUTTLE

- Delivery of Tended and Untended Payloads and Satellites to Low Earth Orbit
- Repair and Retrieval of Spacecraft
- Delivery of Propulsive Stages and Satellites to Low Earth Orbit for Transfer to High-Energy Orbits
- Delivery of 29,500 kg (65,000 lbs.) of Payload to 150-nmi circular Orbit (Due East)
- Delivery of 14,500 kg (32,000 lbs.) of Payload to Polar (98°) 150-nmi Circular Orbit and Retrieval of 11,400 kg (25,000 lbs.) of Payload in a Single Flight

SPACELAB

- Payload Capability: 4,800-8,800 kg (10,600-19,400 lbs.)
- Pressurized Volume: 8-22 m<sup>3</sup> (282-777 ft<sup>3</sup>)
- Average Electrical Power: 3-5 kW
- Payload Specialists: 1 to 4
- Nominal Mission: 7 Days

IUS

- Delivery of up to 2,270 kg (5,000 lbs.) to Geosynchronous Orbit
- Delivery of 680-2,270 kg (1,500-5,000 lbs.) to Sun-Synchronous Orbit from Kennedy Space Center
- Planetary Capability (Twin Stage with Spinner IUS): 900 kg (1,980 lbs.) to Outer Planets (C<sub>3</sub>=115)

SSUS

- Delivery of 1,050 kg (2,300 lbs.) to Geosynchronous Transfer Orbit (SSUS-D)
- Delivery of 2,000 kg (4,400 lbs.) to Geosynchronous Transfer Orbit (SSUS-A)

TABLE 18 -- ESTIMATED NUMBER OF SHUTTLE FLIGHTS REQUIRED

LAUNCH POINT	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Total
KSC (Orbital Flight Tests)	(1)	(3)													(4)
KSC (Operational Flights)			5	14	15	22	29	36	40	40	40	40	40	40	361
VAFB (Operational Flights)					4	8	12	13	14	15	15	15	15	15	126
Total Operational Flights			5	14	19	30	41	49	54	55	55	55	55	55	487

Two additional factors must be considered in determining fleet size. The first is that, by the mid 1980s, this Nation's space activity will be dependent on the STS. The other has to do with the possibility of loss of a Shuttle. The probability of loss is low. However, if one were to occur, it could seriously disrupt the national space program. Considering those two factors and the expected growth in space activities, we have concluded that the 4-Shuttle fleet being built will be adequate during the early years of STS operations, but that a fifth Shuttle will be needed in later years.

The current production program will provide certain items that have long lead-times and that are necessary to ensure efficient production of a fifth Shuttle. While an early go-ahead decision on the fifth Shuttle would save some cost, a moderate postponement of the decision would not incur major additional costs and would provide time for assessing more completely the need for the fifth Shuttle. Deferral of go-ahead beyond 1983 would entail high risk of schedule extensions and prohibitive cost penalties to reestablish phased-out subcontractor capabilities.

This plan includes production of the fifth Shuttle.

## 2. Space Flight Operations

Space flight operations encompass all the activities required to plan, schedule, and conduct space missions. They include a variety of elements such as people, ancillary flight hardware, facilities, plans, and operating procedures. They include facilities and equipment on the ground, flight crews, launch crews, flight planning and mission control functions, supporting computers and communications links, logistics support, planning and scheduling functions, user interfaces, and overall management of the complete enterprise.

This second major activity of the Space Transportation Systems program consists of current work that has been approved, in the sense that it is included in the budget runout, and of work we plan to initiate in 1981 to upgrade the Shuttle in a number of ways. It includes operations with expendable launch vehicles, as well as with the Shuttle.

### a. Current Programs

#### (1) Expendable Launch Vehicles (ELVs)

ELVs currently support NASA launches and the launches of other U.S. Government, international, and commercial agencies and organizations. From 1981 through 1984, we will phase ELVs out as the Shuttle takes over all our launching commitments. During this period, however, we will maintain an ELV capability as a back-up in case of a slip in the Shuttle's schedule.

#### (2) Shuttle

Starting with its first operational flight in 1982, the Shuttle will rapidly replace ELVs as this Nation's launch vehicle. It will reintroduce into the space flight operations equation the factor of flight crews. Another major difference the Shuttle will bring is reusability, with an attendant capability for rapid turn-around between flights. The most

important improvement it will provide, however, is its versatility. That versatility will challenge our ability to make the most effective possible use of this new system.

#### b. Shuttle Changes and System Upgrading

This plan provides funding, starting in 1981, for changes that initial flight tests and preparations for the tests show are needed in the Shuttle and for upgrading the Shuttle to increase its reliability and lower its operating costs. Typical changes under consideration for 1980 and 1981 include improvements in actuators and auxiliary power units, reconfiguration of the radiators, and improved window coatings for the Orbiter. Potential changes to improve the launch and landing systems at KSC include improvements in the checkout equipment and procedures for the launch processing systems, in the control and monitor subsystem, in the central data system interface system, and in the communications system.

Recent studies have shown that there are, in addition to those product improvements, two potential areas for Shuttle growth. The first, augmentation of the Shuttle's thrust via an auxiliary liquid rocket booster, is described below. The second, development of a heavy-lift launch vehicle derived from Shuttle components, is planned for the 1990s and is not described further in this report.

### 3. Space Systems Engineering

Space Systems Engineering consists of analytical, design, and hardware activities leading to new initiatives to improve capabilities in all three of the elements of the Space Transportation Systems program -- transportation, satellite services, and space platforms. Figure 31 shows the planned evolution of capabilities, with those currently funded shown in shaded areas. The evolution of capabilities follows a phased approach, in accordance with need for step-by-step progress.

#### a. Transportation

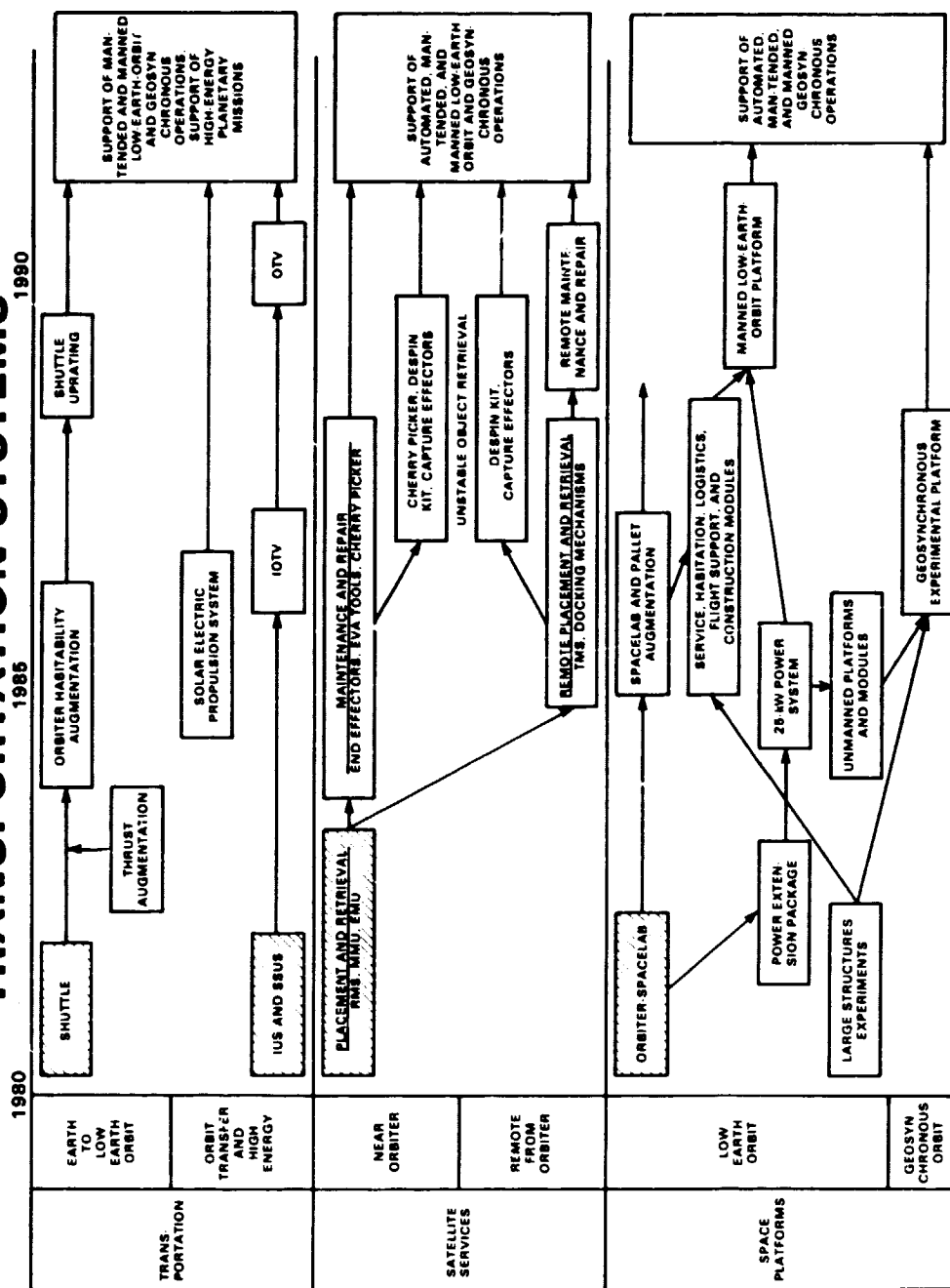
This plan is divided into transportation from Earth to low Earth orbit and transfer to orbits above low Earth orbit.

##### (1) Current and Planned Program

The Shuttle is in development and is expected to become operational in 1982. By 1984, its thrust will have to be augmented for Air Force missions from VAFB requiring placement of 32,000-lb payloads into a 98-degree polar orbit. Preliminary studies have shown that adequate thrust can be provided either by strap-on, solid-rocket boosters or by replacing the Shuttle's present Solid Rocket Booster with a liquid rocket booster (LRB).

We are continuing to study both of these forms of augmentation, not only to meet the 1984 VAFB requirement, but also in anticipation of their need in the early 1990s in connection with large space systems. The LRB appears particularly attractive. It has the potential for increasing the Shuttle's payload delivery capability from 65,000 pounds to 100,000 pounds, with essentially no change in the Orbiter and no increase, possibly even with a decrease, in cost per flight.

# **FIGURE 31 — EVOLUTION OF SPACE TRANSPORTATION SYSTEMS**



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7 25 80

The need for longer stay times in orbit in the mid 1980s will require improvements in the habitability of the Shuttle, and the experience gained in making those improvements will be of great value in developing later life-support systems.

The lower half of the Transportation part of Figure 31 shows the planned evolution of transportation capabilities for missions requiring high-energy propulsion. The ability of the STS to provide easy access to space will increase our operational flexibility and decrease the cost of space transportation. In its early years, the STS will be our sole means for deploying, fabricating, and servicing payloads and structures in space. However, propulsion systems to augment the STS will be required for the higher velocity planetary missions planned for the mid and late 1980s, and for deploying and servicing the geosynchronous platforms and large space systems planned for the late 1980s and early 1990s. We plan to satisfy those requirements with various combinations of the Solar Electric Propulsion System (SEPS), IUS, SSUS, orbital transfer vehicles (OTVs), and beyond the time of this plan, the Shuttle-derived heavy-lift launch vehicle mentioned in Table 16 and in the Space Flight Operations section of this report.

## (2) New Initiatives

### (a) Solar Electric Propulsion System

NASA will use the IUS, under development by the Air Force, for some high-energy missions, including some automated planetary missions. However, we will need an additional kind of propulsion system for some other high-energy missions, especially some automated planetary missions. SEPS is one concept we have been studying and developing technology for during the last two decades. It is a low-thrust ion propulsion system. Teamed with the IUS or, later, an OTV, SEPS is expected to be able to deliver 50,000 pounds of cargo to geosynchronous orbit instead of the 5,000 pounds that the IUS alone will be able to deliver.

### (b) Orbital Transfer Vehicles

Scheduled for initiation in 1983, the OTV will give the STS an ability to deploy large systems, such as space platforms, to geosynchronous orbit, and to service them there. It also will enable the STS to perform such advanced missions as disposing of nuclear wastes and demonstrating space-power technology. We are studying how the diverse needs for an OTV can best be accommodated. Both a cargo OTV and a manned OTV may be needed in the 1990s. In addition, some large structures to be transferred to high orbits may be able to withstand only the limited forces that a low-thrust chemical propulsion system can provide.

We are studying the addition of an Interim OTV (IOTV) to our program to support a 1987 launch of a demonstration geosynchronous-orbit platform. An IOTV using the existing RL-10 rocket engine could possibly transfer to geosynchronous orbit payloads two to three times as heavy as the payloads the IUS will be able to transfer. It also might provide a throttling capability that would satisfy the low-thrust propulsion needs of some cargos. The concept of an IOTV kind of system originated in the Space Tug

studies of some years ago. Our studies will examine both the possible need for an IOTV and the advantages and disadvantages of an IOTV relative to other possible means for satisfying the need.

#### b. Satellite Services

##### (1) Current and Planned Program

The objectives of the Satellite Services program are to define, develop, demonstrate, and make routine operational use of capabilities for placement, retrieval, and in-orbit maintenance and repair of satellites, and for retrieval of unstable satellites and space debris. Providing those services in locations remote from the Orbiter imposes requirements that are considerably different from the requirements related to providing services in the immediate vicinity of the Orbiter.

##### (a) Services Near Orbiter

Our initial capability for satellite placement and limited retrieval will be provided by the Orbiter-mounted Remote Manipulator System (RMS), the Manned Maneuvering Unit (MMU), and the integrated space suit and backpack called the EMU, for Extravehicular Mobility Unit. However, space systems such as the Long Duration Exposure Facility, Multi-Mission Spacecraft, Space Telescope, and low-Earth-orbit science and applications platforms will require improved and new services, as well as equipment to provide those services. The needed equipment will include maintenance and repair tools, berthing platforms, end effectors (mechanical hands) for the RMS, tools for crew members to use in extravehicular activity (EVA) servicing operations, a remote work station called the Cherry Picker mounted to the free end of the RMS' arm, and television systems. We plan to demonstrate all those items of equipment in the 1984-1985 period.

By about 1986 or 1987, we should be able to retrieve unstable satellites and debris near the Orbiter by use of the front end kits to be developed for the Teleoperator Maneuvering System (TMS) described below.

##### (b) Services Remote from Orbiter

Development of the TMS to provide significant services to satellites remote from the Shuttle will benefit considerably from the technology developed for the recently terminated Teleoperator Retrieval System that we had planned to use to boost Skylab to a higher orbit. We are considering two potential modes of operation for the TMS: an Orbiter-controlled mode for retrieval and servicing up to line-of-sight limits (2,000 miles) and a ground-controlled mode that would have unlimited range. We can demonstrate the TMS' ability to retrieve objects 500 to 1,000 miles from the Orbiter by the mid 1980s. Its ability to retrieve remote, unstable objects (satellites or debris) will require front end kits to despin, grapple, and capture those objects. We should achieve that ability about 1986 or 1987. By the late 1980s, equipped with a front end having a mechanism for changing spacecraft modules, the TMS will be able to demonstrate an ability to maintain and repair satellites remotely. Demonstration of the ability of a teleoperator service module teamed with an OTV to service a satellite in geosynchronous orbit will also be possible in the 1980s.

## **(2) New Initiatives**

### **(a) Satellite Services Near Orbiter**

Development funds will be required in 1982 to initiate development of selected items of the equipment and tools mentioned above.

### **(b) Tethered Satellite System**

The Tethered Satellite System will consist of a device in the cargo bay of the Shuttle and a tether to which a variety of satellites can be attached. The device in the cargo bay will consist of an extendable and retractable boom for deploying and retrieving a subsatellite attached to the tether, a reel mechanism, and a base platform. The tether will be a line one millimeter in diameter and as long as 100 kilometers. The tethered system will make possible a variety of scientific, engineering, and applications experiments and measurements; for example, electrodynamics experiments, measurements of the structure of the upper atmosphere, chemical releases, ionospheric measurements, geomagnetic field mapping, and determination of gravity gradients. We plan to initiate flight system design in 1981, and development in 1982.

### **(c) Satellite Services Remote from Orbiter**

The Teleoperator Maneuvering System will be a candidate for initiation in 1983.

## **c. Space Platforms**

### **(1) Current and Planned Program**

The Orbiter and the Orbiter-Spacelab combination are platforms with a nominal stay time in space of 7 days, too short a time for maximum benefit to some experiments. Our initial improvement in platform capability will be to equip the Orbiter with the Power Extension Package (PEP), which will increase stay time to 12 to 20 days, depending on orbit inclination. The 25-kW Power System will further increase stay time, significantly increase the level of electrical power and thermal control available to payloads, and provide a contamination-free environment by virtue of its use of control-moment gyroscopes to provide attitude control. Although the Orbiter and Spacelab will satisfy many needs throughout the decade, their natural evolution from sortie-mode operation, in combination with the 25-kW Power System, is to even longer stay times. The 25-kW Power System in a free-flyer mode with instruments and pallet-mounted payloads attached directly to it will provide that evolution with minimal need for modification and integration. The resulting free-flying platform system will be capable of indefinite periods of operation with minimum tending by the Shuttle.

Some experiments in materials processing, physics and astronomy, and the life sciences will have unique requirements for services or will require a pressurized environment. We will satisfy those requirements by developing special modules. Later, when enough science and applications programs can benefit from a geosynchronous orbit location, we will develop suitable geosynchronous platforms, making all possible use of the technology and experience we have derived from development, construction, and operation of low-Earth-orbit platforms.

By the end of the 1980s, the ability to conduct research and construction activities in space in the most economical manner will require a manned platform in low Earth orbit that needs as little control and resupply from Earth as possible. We will evolve that platform during the late 1980s, using to the maximum extent possible the experience we will have gained from all our earlier platform activities.

Larger structures for use in both low Earth orbit and geosynchronous orbit will have to be assembled or fabricated in space. Experiments relating to large space structures during the early 1980s will provide beam fabricating machinery and other hardware for that purpose.

## **(2) New Initiatives**

### **(a) Power Extension Package**

Shuttle-Spacelab missions will require, or be able to benefit greatly from, more electrical power and longer stay times in space than the base-line Shuttle will be able to provide. They will also require flexibility in selection of orbit inclination. To satisfy those needs, we plan to develop PEP, a solar cell array that will be mounted on the end of the arm of the RMS, which will position and hold it outside the cargo bay. PEP will weigh about as much as one of the cryogenic tanks that hold fuel for the Shuttle's fuel cells. It will allow the Orbiter to fly a variety of orbit inclinations and increase flight duration and electrical power available to payloads.

### **(b) 25-kW Power System**

The 25-kW Power System will satisfy the requirements of Shuttle-Spacelab sortie missions needing more power and longer stay times than the base-line Orbiter or the PEP-equipped Orbiter will be able to provide. In this mode of operation, it will be berthed (soft-docked) to the Orbiter to provide electrical power, thermal control, and contamination-free attitude control to the payloads in the cargo bay and to payloads connected directly to it. It will also function in the free-flying mode at a fixed inclination in low Earth orbit. In this mode, it will provide those services to the instrument pallets and modules described below, which will be attached to it for long periods, and will be serviced only from time to time by the Shuttle.

Together, PEP and the 25-kW Power System will provide a range of capability that will give the STS flexibility to satisfy a wide variety of science and applications needs during its first decade of operations.

### **(c) Science and Applications Platform**

As mentioned above, future science and applications payloads will benefit from more electrical power than will be available on Shuttle-Spacelab sortie missions. Also, studies have shown that they will benefit from an ability to operate in both Shuttle-tended and longer duration, free-flyer, untended modes. Further, the operation of a number of currently planned free-flyer payloads may be enhanced by combining the payloads on a platform providing support systems common to all the payloads. To provide this capability, we plan to develop a science and applications platform that

will operate in conjunction with the 25-kW Power System. Our approach will be evolutionary, possibly with modified European Space Agency pallets attached directly to the 25-kW Power System as the first step. Our ultimate objective is to develop a system that uses the 25-kW Power System most effectively to accommodate a wide range of users.

(d) Materials Experiment Carrier (MEC)

The Office of Space and Terrestrial Applications' analyses of the cost of performing systematic, sustained, research on the processing of materials in space have shown that longer stay time in orbit and more electrical power for the experiments can significantly reduce the unit cost of research. MEC will accommodate automated materials-processing payloads and, with the 25-kW Power System, make extended duration operations efficient and practical.

As currently conceived, MEC will be a structure that can be docked to the 25-kW Power System to support research in materials for periods of up to 90 days. It will provide the mechanical, electrical, and thermal interface between the 25-kW Power System and the materials-research payloads. The interface requirements are currently under study. MEC will provide an orderly transition between early exploratory research activities and later research and development programs that will capitalize on the results of those early activities.

(e) Materials Experiment Carrier II (MEC II)

The later research and development programs mentioned in the preceding paragraph will be carried out on MEC II. We do not yet know the requirements for MEC II sufficiently to define its configuration, select its initiation date, or estimate its funding requirements. However, we expect it to be a growth version of MEC that will permit the amount and cost of materials research and development to be conducive to industrial research. We expect it to accommodate 2,500 to 7,500 kilograms of processing apparatus having a volume of 9 to 19 cubic meters, to provide enough heat rejection capability to utilize fully the resources of the 25-kW Power System, and to be able to maintain acceleration maxima of  $10^{-6}$  g. A mix of tended and automated operations will permit MEC II and its equipment to operate almost continuously, and its design will provide further evolution to meet expected increases in research requirements in the late 1980s.

(f) Large Space Structures Systems Engineering

NASA's Office of Aeronautics and Space Technology (OAST) is currently engaged in ground-based development of technology for large space structures. This program will be a 10-year, level-of-effort, study activity to extend OAST's results to an experimental program in space. It will demonstrate fabrication, deployment, erection, and assembly of booms, trusses, and precision structures such as antennas that could satisfy the future needs of a broad cross-section of users, but not be dependent on any of the users for approval.

As a part of our demonstration program, we have a joint project with the Department of Defense to demonstrate a deployable antenna. That joint project will continue to receive special emphasis and is expected to be our first flight demonstration.

(g) Geostationary Platform Demonstration

Recent NASA studies have shown that a geostationary platform serving as host to a wide spectrum of payloads will have distinct advantages over the traditional approach of using numerous specialized satellites to accommodate those payloads in geosynchronous orbit. Typical payloads include meteorology and Earth-resources observing systems, scientific instruments, and antennas and transponders for communications applications such as domestic satellite services, mobile services, maritime services, and educational TV broadcasts. A geostationary platform could carry large-aperture antennas whose multiple, narrow beams and ability to switch signals from beam to beam and antenna to antenna may provide a means for limiting the radio interference that users of geosynchronous orbits face in the late 1980s, perhaps even at a cost saving that can be passed on to users. Current planning includes an initiation date of 1983 for a Geostationary Platform Demonstration and an initiation date of 1987 for an operational platform.

(h) Space Operations Center Core

The Space Operations Center (SOC) is one concept of a Shuttle-serviced, permanent facility in low Earth orbit. It will improve the efficiency of orbital operations such as the construction, check out, and transfer to operational orbit of large, complex space systems; in-orbit assembly, launch, recovery, and servicing of manned and unmanned spacecraft; tending of co-orbiting free-flying satellites; and continuing development of our capability to conduct permanent manned operations in space with progressively less dependence on Earth for control and resupply. The starting point of this evolutionary facility will be a core element containing service modules that provide electrical power; guidance, control, and stabilization; reaction control; and communications. The core element will have airlocks for extravehicular activity and docking ports for the Orbiter and other modules such as those discussed in the next paragraph. It will interconnect all those modules and provide a pressurized passageway between them. Initiation of development of the SOC core is planned for 1984.

(i) Space Operations Center Modules

Evolution of the SOC core element to a manned facility will require development of a habitation module. We plan to initiate in 1985 development of a module containing a command center; private quarters; food preparation, hygiene, and waste management facilities; exercise and recreation equipment; and a health maintenance facility with a small laboratory. Other typical kinds of modules that will be required for a fully operational manned SOC are a logistics module, a construction facility for fabrication of large space systems, and a flight support facility for servicing upper stages, OTVs, and co-orbiting satellites.

(j) Space Power Systems Engineering

Various studies have indicated the need for a 200- to 500-kW power module in the late 1980s to support such space operations as materials processing; space construction, including the construction of advanced communications systems; and other science and applications projects. That module probably will be constructed in space with the aid of the 25-kW Power System and other systems, such as a remote service module. The Office of Space Transportation Systems will continue to work with the other NASA program offices to determine what the next step beyond the 25-kW Power System should be. Many items of equipment that will be developed for use with the 25-kW Power System and SOC could later be used directly with this larger power module.

(k) Space Power Technology Demonstration

Studies have indicated that space solar power is potentially competitive with other means for satisfying humanity's energy needs on Earth. Its economic viability will depend on significant improvement in the cost or energy-conversion efficiency of solar cells and on lower space transportation costs. Its technical feasibility will depend on development of efficient techniques for transmitting microwave power from space to Earth and for constructing large systems in space. Space solar power technology could be demonstrated either by constructing and operating a test article in space or by attaching a transmitting antenna to an available space power system. NASA's Office of Energy Systems is working with the Department of Energy to define the concept for a space solar power system. Given that concept, the Office of Space Transportation Systems will be able to initiate development of space systems to demonstrate and test it.

F. Schedule and Funding

Table 19 shows the phasing of the Space Transportation Systems program and Figures 32 and 33 show the program's funding requirements. Those funding requirements do not include funding for Spacelab, which is being developed by the European Space Agency; the IUS, which is being developed by the Air Force; or the two classes of the SSUS, which are being developed by industry. In addition, as shown on Figures 32 and 33, some of the funding requirements are yet to be determined for the IOTV, Geostationary Platform Demonstration, and geosynchronous satellite services.

TABLE 19 -- SPACE TRANSPORTATION SYSTEMS PROGRAM SCHEDULE

PROGRAM	RESPONSIBLE FIELD CENTERS *	PROGRAM PHASE			ADDITIONAL IMPORTANT INFORMATION
		DEFINITION	INITIATION	INITIAL OPERATING CAPABILITY	
Shuttle DDT&E	JSC, KSC, MSFC	Completed	1972	--	Completion 1981
Shuttle Production	JSC, KSC, MSFC	Completed	1977	1982	Ongoing
Shuttle Upgrading	JSC, KSC, MSFC	Ongoing	1981	--	Launches as needed; completion 1984
Expendable Launch Vehicles	GSFC, KSC, LeRC MSFC, WFC	Completed	--	1958	Launches as needed
Solar Electric Propulsion System	MSFC	Ongoing	1982	1986	Launches as needed
Interim Orbital Transfer Vehicle	LeRC	Ongoing	1983	1987	Launches as needed
Orbital Transfer Vehicle	**	Ongoing	1985	After 1990	Launches as needed; manned capability to be added later
Satellite Services Near Orbiter	JSC, MSFC	Ongoing	1982	1985	Includes Tethered Satellite System
Satellite Services Remote from Orbiter	JSC, MSFC	Ongoing	1983	1986	Includes Teleoperator Maneuvering System; intermediate capability 1985
Geostationary Satellite Servicer	**	Ongoing	1984	1987	Shuttle-mounted system
Power Extension Package	JSC	Ongoing	1982	1984	Shuttle auxiliary power or free flying
25-kW Power System	MSFC	Ongoing	1982	1985	Includes deployable antenna; continuing activity
Large Space Structures Systems Engineering	LaRC	Ongoing	1982	1985	Intermediate capability 1985
Science and Applications Platform	MSFC	Ongoing	1983	1986	Initiation of operational platform: 1987
Materials Experiment Carrier (MEC) and MEC II	MSFC	Ongoing	1983	1986	Low Earth orbit; Shuttle serviced
Geostationary Platform Demonstration	MSFC	Ongoing	1983	1987	Habitation, logistics, construction, and flight support modules
Space Operations Center Core	JSC	Ongoing	1984	1987, 8	Space power for use in space
Space Operations Center Modules	JSC	Ongoing	1984, 5, 6	1987, 8, 9	Space solar power for use on Earth; joint definition effort with Department of Energy
Space Power Systems Engineering	**	Ongoing	**	**	
Space Power Technology Demonstration	**	Ongoing	**	**	

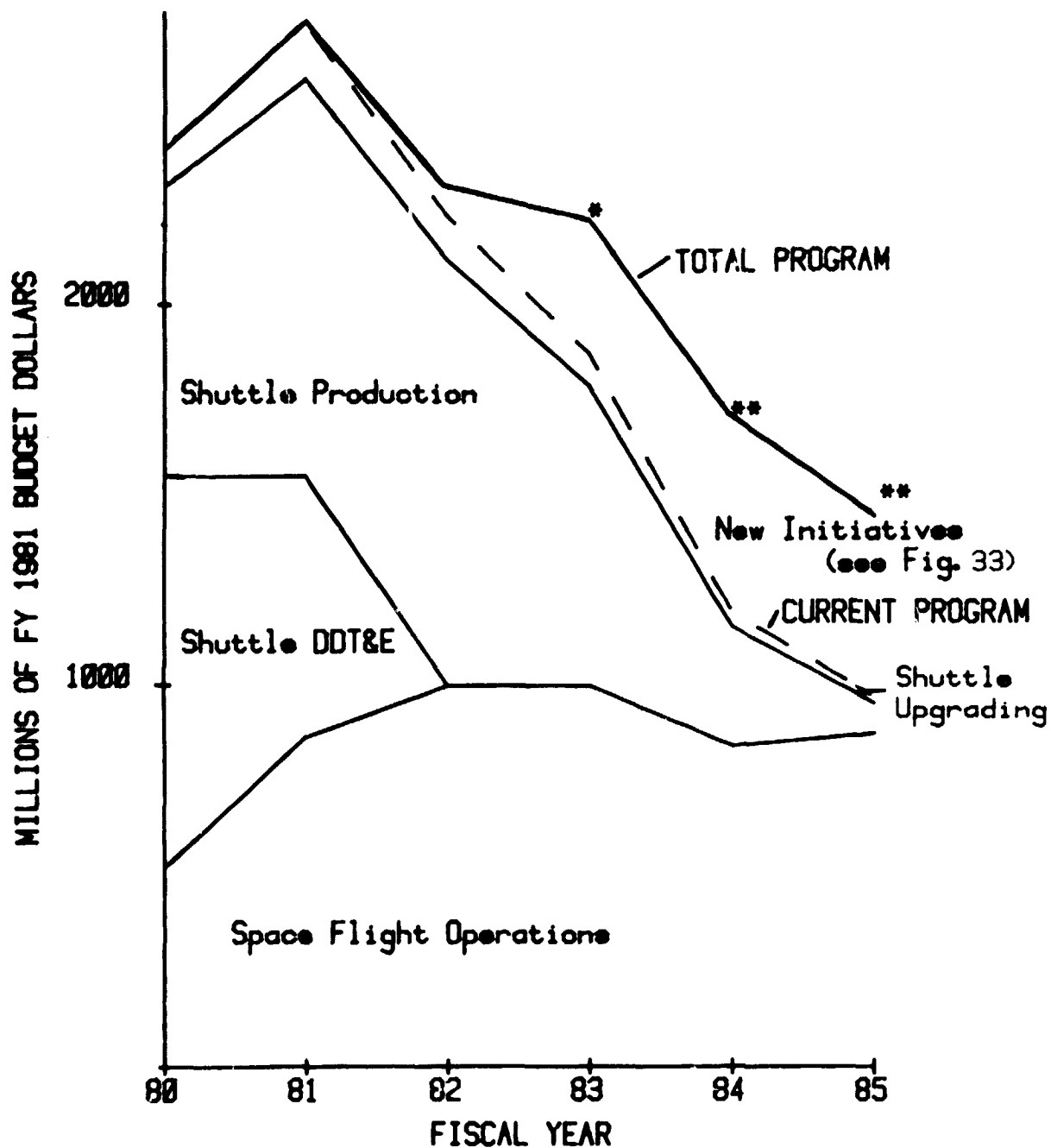
\* GSFC = Goddard Space Flight Center      LeRC = Lewis Research Center      \*\* To be determined

JSC = Johnson Space Center      MSFC = Marshall Space Flight Center

KSC = Kennedy Space Center      WFC = Wallops Flight Center

LaRC = Langley Research Center

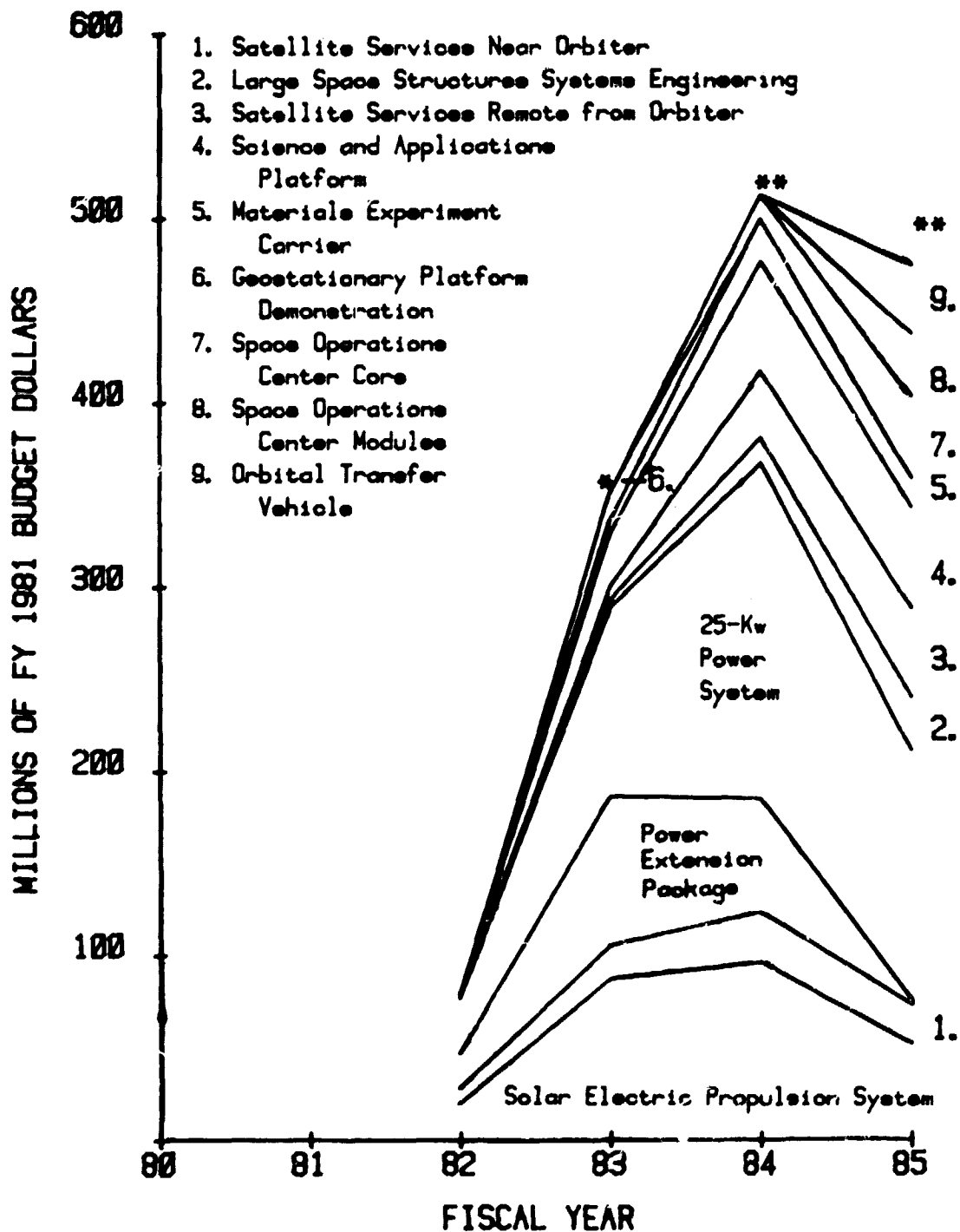
FIGURE 32.  
SPACE TRANSPORTATION SYSTEMS PROGRAM FUNDING



\*Does not include funding for Interim Orbital Transfer Vehicle (IOTV).

\*\*Does not include funding for IOTV, Geostationary Platform Demonstration, and Geostationary Satellite Services.

**FIGURE 33.  
SPACE TRANSPORTATION SYSTEMS  
NEW INITIATIVES FUNDING**



\*,\*\*See footnote, Figure 32.

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## IX. SPACE TRACKING AND DATA SYSTEMS PROGRAM

The Space Tracking and Data Systems program consists of four major elements:

- o Operation of a worldwide network of tracking antennas, laser tracking systems, mission control centers, and data processing facilities linked together by a global communications system comprised of land-lines, underseas cables, and microwave and satellite channels
- o A program of systems implementation that ensures the design, development, installation, implementation, and check-out of special and improved equipment systems in the tracking and data network to support NASA's many and varied programs
- o A program of advanced research and development to improve the state of the art in such areas as tracking, telemetry, and ground-based and spacecraft navigation techniques; spacecraft-to-ground communications; ground-control station operations and methods; data transmission, processing, storage, and cataloging techniques; and productivity improvements
- o A Tracking and Data Relay Satellite System (TDRSS) that will take over the tracking and data acquisition support of all low-Earth-orbiting spacecraft, significantly enhance support capability, effect economies through station closures and network consolidation, and increase the automation of operations.

Combined, these elements provide the tracking, data acquisition and processing, and communications capability required to support NASA's Earth-orbital applications and science missions, interplanetary missions, and aeronautical and sounding rocket programs.

The Space Tracking and Data Systems program has evolved over the past decade from three distinct, mission-unique networks, with their attendant data processing systems, into a more unified system with a multipurpose capability. This trend will continue. The Shuttle era will provide numerous flight opportunities that will dramatically increase the volume of data and will force further standardization and commonality of our data systems.

### A. Goals and Objectives

The goal of the Space Tracking and Data Systems program is to develop, implement, and operate the tracking and data systems required for the successful, efficient accomplishment of flight missions of both automated and manned orbital spacecraft, deep space probes, sounding rockets, balloons, and research aircraft.

The objectives the program must fulfill to achieve that goal are to:

- o Support a wide variety of missions using methods that become increasingly more standardized
- o Maximize the information return from flight missions while reducing the costs for obtaining that return
- o Process large volumes of data at increasingly higher data rates with reliable systems that are insensitive to the data loads imposed on them

- o Improve the acquisition, transfer, processing, and distribution of data for analysis
- o Improve tracking precision and deep-space navigation accuracies
- o Evaluate techniques and technologies for future systems
- o Identify the frequency-spectrum requirements of each program and initiate action to obtain national and international access to the required frequency-spectrum areas.

#### B. Planning Assumptions

During the next several years, NASA's tracking and data systems must increase significantly in their ability to handle ever greater volumes such as those that will be characteristic of the complex sensors, spacecraft, projects, and science experiments of the Space Shuttle era. New capabilities, techniques, and systems will be required. To make possible the planning required for satisfying the increasingly rigorous requirements, the Office of Space Tracking and Data Systems (OSTDS) made the following major assumptions:

- o The Tracking and Data Relay Satellite System (TDRSS) currently under development to provide high data rates to Earth-orbiting space missions will become operational in 1984.
- o All low-Earth-orbit systems initiated after 1980 will be compatible with TDRSS.
- o The first Spacelab launch will be in of 1983.

#### C. Program Strategy

The size and content of the Space Tracking and Data Systems program are directly related to the activities in NASA's space and aeronautics programs. The services the program supplies are vital to all flight programs, and there are various ways to provide them. The program's strategy is to balance the unique needs of each flight mission with the efficiencies achieved by use of multimission, general purpose systems and facilities.

#### D. Program Emphasis

During the next five years, the Space Tracking and Data Systems program will concentrate on the following:

- o To work closely with the contractor to launch and operate the first generation of the geosynchronous tracking and data relay satellites that will comprise the spaceborne portion of the TDRSS
- o To phase out ground tracking stations whose services would be redundant to those offered by TDRSS
- o To consolidate and reconfigure the remaining tracking stations in the Spaceflight Tracking and Data Network (STDN) and the Deep Space Network (DSN) into one general purpose network under the management of the Jet Propulsion Laboratory, and to standardize the network's operational procedures

- o To explore and adopt new concepts and techniques for acquiring, processing, transferring, and managing data in order to enhance mission coverage, improve data handling efficiency, and reduce costs
- o To extend the reception capability and sensitivity of existing antenna systems by increasing use of multiple antenna arrays and by improving receiver sensitivity and signal processing techniques
- o To study concepts for and the feasibility of second-generation communications-relay satellites in geosynchronous orbit to support both Earth-orbital and planetary missions in the 1990s
- o To address the frequency-spectrum requirement implications of all the above actions.

#### E. Program Changes from 1980 through 1984 Plan

Delays in the Space Shuttle program have affected the activities and the progress of the Space Tracking and Data Systems program. The operational date for the TDRSS has been delayed to 1984, and this delay will require keeping the stations in the STDN operational longer. These changes affect the funding requirements shown in Figure 34, which reflects a one-year delay in the leasing of TDRSS services.

#### F. Program Content

##### 1. Data Acquisition and Tracking

Initiation of TDRSS services will usher in a new era in data acquisition. Two satellites in geosynchronous orbit and a single ground terminal will take over the tracking and data acquisition functions for all satellites in low Earth orbit, including the Shuttle. The system will minimize costs by increasing mission coverage while allowing a majority of the current ground stations to be phased down.

Conversion of both 26-meter subnets of the DSN to 34-meter subnets with dual-frequency S- and X-band capability will improve the capabilities of that network. The combining of signals received by two or more antennas will further increase signal strengths and data rates. This arraying technique offers considerable potential, and OSTDS is considering the use of antennas from the STDN in this way.

Another technique planned for use to provide the precision in location and trajectory information necessary for navigating spacecraft is differential very-long-baseline interferometry. That technique will correlate known solar system dynamics with data from the spacecraft, two ground stations, and a cataloged stellar radio source to yield a precise plot of the characteristics of the spacecraft's trajectory.

##### 2. Data Transmission and Processing

Modernization and adaptation of existing data transmission and processing systems have already begun. The Telemetry On-Line Processing System recently became operational, and conversion of the Image Processing Facility at Goddard

Space Flight Center to a completely digital system is progressing. Planning is continuing for a new system able to process the large volumes of data that Spacelab will generate. The data output from one Spacelab can exceed that from all concurrent non-imaging free-flying spacecraft.

OSTDS will explore and test concepts and techniques to determine the feasibility of using standard data formats and of preprocessing data (editing, cataloging, and annotating data) aboard spacecraft to decrease the need for manipulating data in the large computer systems on the ground. OSTDS will prepare a set of standards and guidelines for data acquisition, processing, and transmission that can be accommodated by spacecraft hardware to allow annotation of data streams before their transmission to the ground. This procedure will permit transfer of usable data in near real time from spacecraft experiments to the users.

Increasing use of wide-band communications via satellites will be a hallmark of the program in the 1980s. Real-time transfer of data through satellite communications will become standard for the Shuttle, its complex payloads, free flyers, and the new generation of deep space missions.

All these data transmission and processing techniques and systems will enable NASA to process larger volumes of data, increase the operating flexibility of mission control functions, speed up the transfer of real-time data, and get processed data to investigators more rapidly.

### 3. Subspace Support

A phased program to upgrade and replace equipment will ensure that flights of sounding rockets, balloons, and research aircraft will continue to receive adequate support. OSTDS will investigate promising new technologies and techniques that could help maintain high reliability and low costs in supporting those multifaceted missions. OSTDS also will study and evaluate for future application such items as ultraprecise time standards and synchronization and fiber-optics communications.

### 4. Major Initiatives in Process

#### a. Spacelab Data Processing Facility

Spacelab will create an immense growth in the volume of data requiring general purpose processing. In supporting early Spacelab flights, OSTDS will make maximum use of the existing data processing system by making special augmentations to it and by placing constraints on Spacelab's data rates. Those techniques will enable the processing of data from the early flights in a timely manner with only minimum impact on the processing of data from free-flying spacecraft. However, those techniques will become less and less effective as the data rates from planned experiments and the frequency of Spacelab missions increase. Thus, an important continuing activity is to adopt new concepts that increase the efficiency of data transfer and processing. OSTDS currently is analyzing several evolving concepts and the costs of adopting them. Those that prove feasible and reasonable will be recommended for use on Spacelab missions and on free-flyer missions, as well.

b. X-Band Command System

Addition of an X-band up-link command system to the DSN will permit commanding a spacecraft at a much smaller angular separation from the Sun (Sun-Earth-probe angle) than is currently possible with the S-band uplink. For example, the current S-band system does not provide an ensured ability for commanding a spacecraft at Jovian distance with a Sun-Earth-probe angle less than  $15^{\circ}$ . The result is an absence of command capability for a period of up to 30 days. An X-band system will reduce that time to 3 days.

c. NASA Data Management System

A study group composed of representatives from each program office in the Headquarters and currently chaired by the Office of Space Tracking and Data Systems has been established to determine an optimum structure and guidelines for a data system to support NASA missions. The group will make recommendations to NASA management on both input (spacecraft end) and output (user end) systems. Each program office will implement the recommendations for its program area.

5. New Initiatives

a. Network Consolidation

When TDRSS becomes operational, NASA will close all except six of the stations in the STDN and will maintain full operations only at Goldstone, California; Madrid, Spain; and Canberra, Australia. Since those three stations are collocated with the stations in the DSN, OSTDS has studied their consolidation under a single management. The study clearly showed that consolidation under Jet Propulsion Laboratory management will provide technical and economical advantages. On October 2, 1979, the NASA Administrator approved the consolidation, and detailed planning and implementation began.

b. Orbiting Deep Space Relay Station

Communications with distant spacecraft performing deep-space missions in the 1990s are expected to require improvement over those available today. An Orbiting Deep Space Relay Station could provide that improvement, performing for deep-space missions a function similar to that which TDRSS will perform for Earth-orbiting missions. OSTDS plans to initiate in 1981 studies to identify technologies for, assess the feasibility of, and examine other parameters relative to such a station.

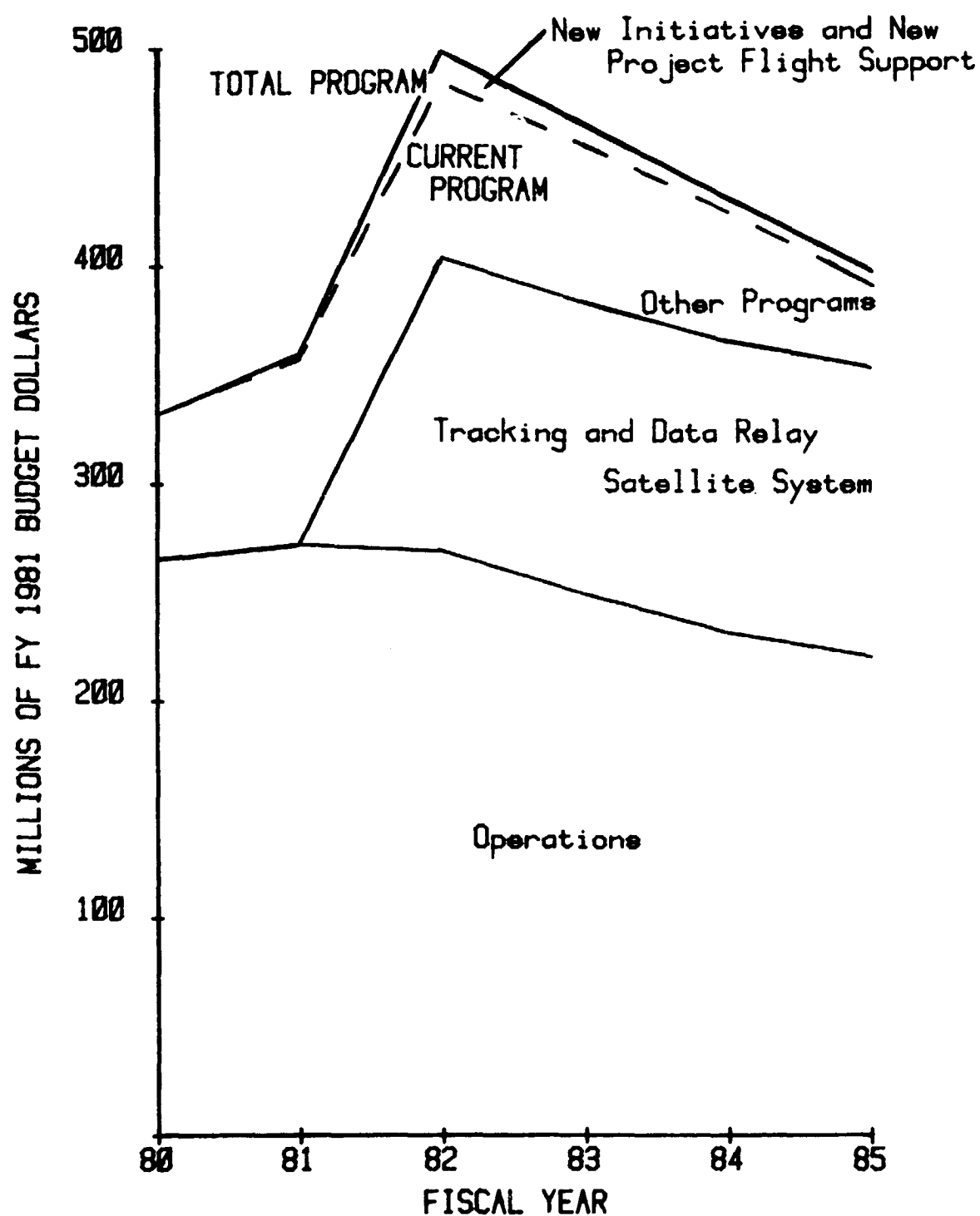
G. Schedule and Funding

Table 20 shows the phasing of the Space Tracking and Data Systems program and Figure 34 shows the program's funding requirements.

TABLE 20 -- SPACE TRACKING AND DATA SYSTEMS PROGRAM SCHEDULE

PROGRAM	PROGRAM PHASE		
	DEFINITION	INITIATION	LAUNCH OR INITIAL OPERATION
Tracking and Data Relay Satellite System  Spacelab Data Processing Facility: Interim Final  X-Band Command System  Network Consolidation  Packet Oriented Data System  Orbiting Deep Space Relay Station	Completed	1976	1982 (First launch)
	Ongoing	1980 Post 1982	1982 Post 1985
	Ongoing	1980	To be determined
	1980	1981	To be determined
	1980	1981-1982	1985
	1981	To be determined	To be determined

FIGURE 34.  
SPACE TRACKING AND DATA SYSTEMS PROGRAM FUNDING



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## X. CONSTRUCTION OF FACILITIES PROGRAM

NASA's research and development capabilities are based on a sensitive balance of qualified and dedicated people, available funds, and adequate facilities. The Construction of Facilities (CoF) program provides those adequate facilities not only to NASA's "primary" program offices (Space Science, Space and Terrestrial Applications, and Aeronautics), but also to its "supporting" program offices (Space Technology, Space Transportation Systems, Space Transportation Operations, and Space Tracking and Data Systems).

### A. Program Goals

The goals of the CoF program are to ensure the adequacy of NASA's existing facilities, to upgrade and modify those facilities to meet new requirements, and to acquire new facilities, when necessary.

### B. Program Strategy

The CoF program's procedure for providing timely, effective, and economical support to all of NASA activities is to:

- o Participate in the development of facility requirements
- o Analyze facility needs and explore alternative methods for reducing facility costs
- o Repair and rehabilitate existing facilities clearly needed in the future
- o Modify existing facilities to meet new requirements, when possible, to minimize the need for new facilities
- o Construct new facilities when other alternatives are less cost effective.

### C. Program Content

The CoF program stems from continuous efforts to anticipate the needs of NASA's major projects. Those needs can usually be met by preserving and enhancing existing facilities; the Agency's planned research activities have generated few requirements for new facilities. Consequently, most of the approximately 150 projects in the program will cost only \$1 million to \$15 million each and will consist of rehabilitation or modification of facilities. Representative categories of projects in the CoF 5-year program and the principal activities comprising the work in each are as follows:

#### 1. Space Transportation System

Modifications to provide facilities for launching and servicing the Space Shuttle and for manufacturing and refurbishing components for it

## 2. Space Shuttle Payloads

Rehabilitations and modifications to provide facilities for: processing the Inertial Upper Stage, Spinning Solid Upper Stages, and scientific experiments and payloads; servicing payloads and integrating them with launch vehicles; and processing data from Spacelab and Landsat projects

## 3. Energy

Modifications to facilities, buildings, and utility systems selected on the basis of the modifications' cost effectiveness in conserving energy and improving energy efficiencies

## 4. Aeronautics

Construction and modifications to provide aeronautical research facilities

## 5. Space Support

Construction and modification of launch facilities, ground-based laboratories and computer areas for analysis of experiments and samples from spacecraft, and test stands for spacecraft and propulsion systems in direct support of the space science, applications, and space technology programs

## 6. Tracking and Data Acquisition

Construction of antennas, and rehabilitation and modification of the ground-based antenna network

## 7. Other

Rehabilitation and modification of roads, parking lots, warehouses, offices, laboratories, shops, and computer facilities that typically support a variety of research programs and are not dedicated to a specific program

## 8. Level of Effort

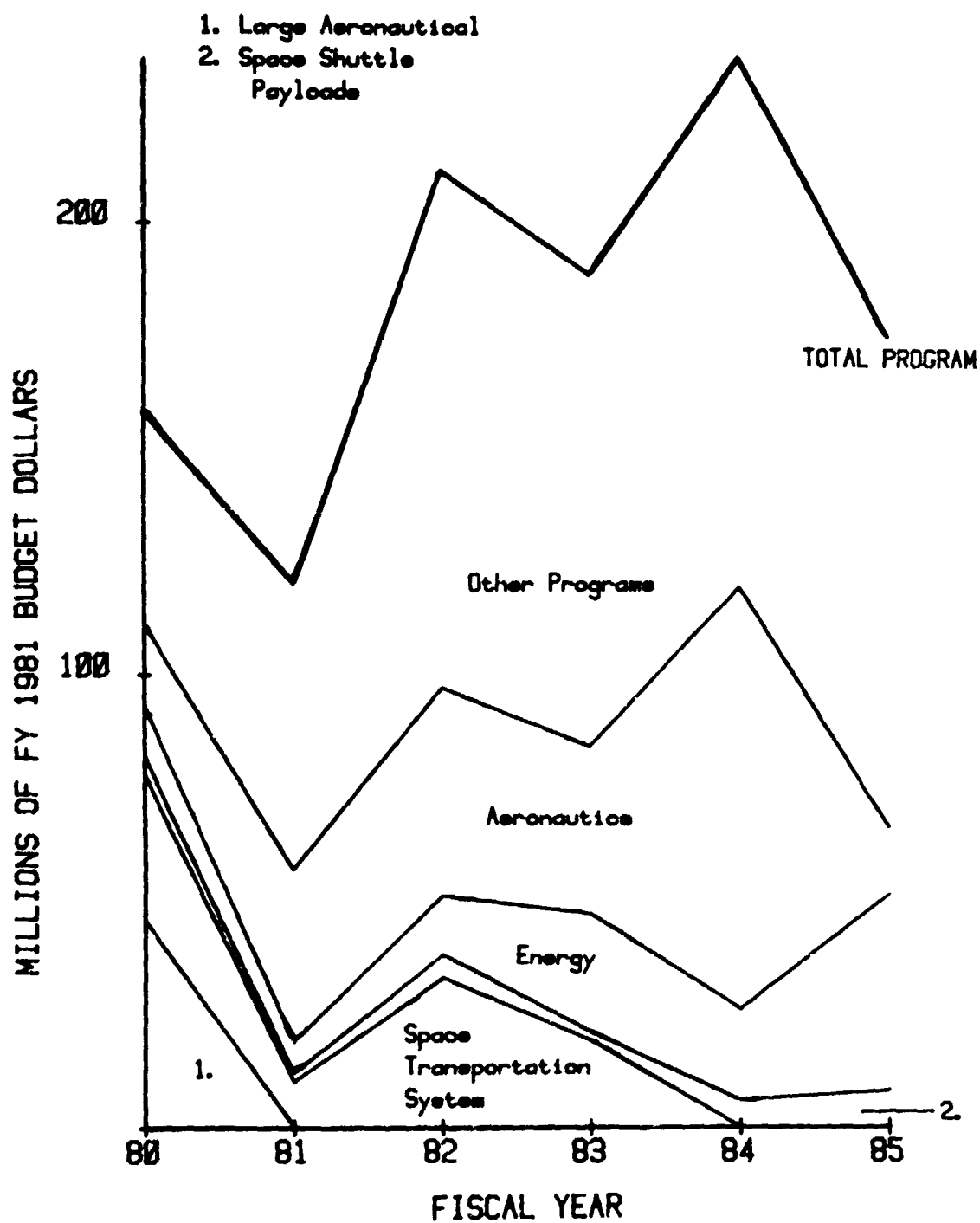
Minor construction, rehabilitation, modification, and repair of existing facilities to preserve their efficient and productive operation, as well as facility planning and design for advanced facilities or proposed major modifications of existing facilities.

## D. Funding

Figure 35 shows estimated CoF funding requirements through 1985. Construction starting dates used in the estimates are the latest dates that will meet the needs of the programs the facilities will support, and the dates for institutional projects are based on "good business judgment" to provide overall cost-effective use of resources. The entire scheduling sequence is regularly confirmed or revised in the CoF program review cycle.

The funding requirement for Large Aeronautical facilities shown in Figure 35 for 1980 is for completion of construction of the National Transonic Facility at Langley Research Center and completion of modification of the 40-foot by 80-foot Subsonic Wind Tunnel at Ames Research Center.

FIGURE 35.  
CONSTRUCTION OF FACILITIES PROGRAM FUNDING



ABBREVIATIONS AND ACRONYMS

ACEE	Aircraft Energy Efficiency
ACPL	Atmospheric Cloud Physics Laboratory
ADS	Applications Data Service
AgRISTARS	Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing
AMPTE	Active Magnetospheric Particle Tracer Explorer
ARC	Ames Research Center
AR&DA	Applied Research and Data Analysis
ASVT	Applications Systems Verification and Transfer
ATMOS	Atmospheric Trace Molecules Observed by Spectroscopy
ATP	Advanced Turboprop Program
ATS	Advanced Technology Satellite
A.U.	Astronomical Unit (Sun-Earth Mean Distance)
AXAF	Advanced X-Ray Astrophysics Facility
b/s	Bits Per Second
CLIR	Cryogenic Limb-Scanning Interferometer and Radiometer
cm	Centimeter
COBE	Cosmic Background Explorer
CoF	Construction of Facilities
COSMIC	Computer Software Management and Information Center
CRF	Chemical Release Facility
CRO	Cosmic Ray Observatory
CTS	Communications Technology Satellite
CZCS	Coastal Zone Color Scanner
DDT&E	Design, Development, Test, and Evaluation
DE	Dynamics Explorer
DFRC	Dryden Flight Research Center
DMA	Defense Mapping Agency
DOD	Department of Defense
DOE	Department of Energy
DSN	Deep Space Network
ELV	Expendable Launch Vehicle
EMU	Extravehicular Mobility Unit
EPA	Environmental Protection Agency
ERBS	Earth Radiation Budget Satellite
ERSAR	Earth Resources Synthetic Aperture Radar
ESA	European Space Agency
EUVE	Extreme Ultraviolet Explorer
EVA	Extravehicular Activity
FIREMEN	Fire Resistant Materials Engineering
FPUP	Federal Photovoltaics Utilization Program
ft	Foot
FY	Fiscal Year
g	Acceleration of Gravity
GARP	Global Atmospheric Research Program
GEO	Geosynchronous Orbit
GEOS	Geodynamic Experimental Ocean Satellite
GHz	Gigahertz ( $10^9$ Hertz)
GOES	Geostationary Orbit Environmental Satellite
GPS	Global Positioning System
GP-B	Gravity Probe-B

# ABBREVIATIONS AND ACRONYMS (CONTINUED)

GRO	Gamma Ray Observatory
Gr-PI	Graphite-Polyamide
GSFC	Goddard Space Flight Center
GWE	GARP Global Weather Experiment
HALOE	Halogen Occultation Experiment
HCMM	Heat Capacity Mapping Mission
HEAO	High Energy Astronomy Observatory
HiMAT	Highly Maneuverable Aircraft Technology
IAC	Industrial Application Center
ICEX	Ice and Climate Experiment
IOTV	Interim Orbital Transfer Vehicle
IR	Infrared
IRAS	Infrared Astronomy Satellite
ISEE	International Sun-Earth Explorer
ISPM	International Solar Polar Mission
IUE	International Ultraviolet Explorer
IUS	Inertial Upper Stage
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
kb/s	Kilobits per Second
kg	Kilogram
km	Kilometer
KSC	Kennedy Space Center
kW	Kilowatt
kWe	Kilowatt Electric
LACIE	Large Area Crop Inventory Experiment
LAMAR	Large Area Modular Array X-Ray Telescope
LaRC	Langley Research Center
lb. (lbs.)	pound (pounds)
LDEF	Long Duration Exposure Facility
LEO	Low Earth Orbit
LeRC	Lewis Research Center
LIDAR	Light Intensification, Detection, and Ranging
LRB	Liquid Rocket Booster
LSA	Low-Cost Solar Array
m	Meter
Mb/s	Megabits per Second
MEC	Materials Experiment Carrier
MERIT	Monitoring of Earth Rotation and Intercomparison of Techniques
MHD	Magnetohydrodynamics
MMU	Manned Maneuvering Unit
μs	Microsecond
MSFC	Marshall Space Flight Center
MW	Megawatt Electric
MW <sub>e</sub>	Megawatt Thermal
NAC	NASA Advisory Council
NASA	National Aeronautics and Space Administration
NGS	National Geodetic Survey
NIHR	National Institute for Handicapped Research
nmi	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration

# ABBREVIATIONS AND ACRONYMS (CONTINUED)

NOSS	National Oceanic Satellite System
ns	Nanosecond
NSF	National Science Foundation
NSTL	National Space Technology Laboratories
NTIA	National Telecommunications and Information Administration
OAST	Office of Aeronautics and Space Technology
ONR	Office of Naval Research
OPEN	Origins of Plasma in Earth's Neighborhood
OSIP	Operational Satellite Improvement Program
OSS	Office of Space Science
OSTA	Office of Space and Terrestrial Applications
OSTDS	Office of Space Tracking and Data Systems
OSTS	Office of Space Transportation Systems
OTEC	Ocean Thermal Energy Conversion
OTV	Orbital Transfer Vehicle
PEP	Power Extension Package
PI	Principal Investigator
PTE	Plasma Turbulence Explorer
R&D	Research and Development
R&T	Research and Technology
RD&D	Research, Development, and Demonstration
RMS	Remote Manipulator System
SAGE	Stratospheric Aerosol and Gas Experiment
SAR	Synthetic Aperture Radar
SCE	Solar Corona Explorer
SEPS	Solar Electric Propulsion System
SERIES	Satellite Emission Radio Interferometric Earth Surveying
SETI	Search for Extraterrestrial Intelligence
SGRS	Spaceborne Geodynamics Ranging System
SIR-A,2,3	Shuttle Imaging Radar-A,2,3
SIRTF	Shuttle Infrared Telescope Facility
SMIRR	Shuttle Multispectral Infrared Radiometer
SMM	Solar Maximum Mission
SOC	Space Operations Center
SOT	Solar Optical Telescope
SPS	Satellite Power System
SST	Supersonic Cruise Transport
SSTAC	Space Science and Technology Advisory Committee
SSUS	Spinning Solid Upper Stage
STAC	State Technology Assistance Center
STDN	Spaceflight Tracking and Data Network
STOL	Short Takeoff and Landing
STS	Space Transportation System
TCV	Terminal Configured Vehicle
TDRSS	Tracking and Data Relay Satellite System
TMS	Teleoperator Maneuvering System
TOPEX	Topography Experiment
UARS	Upper Atmosphere Research Satellites
UHF	Ultra High Frequency

# ABBREVIATIONS AND ACRONYMS (CONTINUED)

USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UV	Ultraviolet
VAFB	Vandenberg Air Force Base
VCE	Variable Cycle Engine
VLBI	Very Long Baseline Interferometer
VOIR	Venus Orbiting Imaging Radar
V/STOL	Vertical and Short Takeoff and Landing
VTOL	Vertical Takeoff and Landing
WFC	Wallops Flight Center
WTG	Wind Turbogenerator
XRO	X-Ray Observatory

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